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Regional Framework for Nature Based Solutions in Southwest BC: CWHxm1 Terrestrial Ecosystem Mapping – Southern Comox Valley Regional District (BAPID 6641)

BCCF Contract #: 4223001-002

For:

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&

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Natural Resource Information & Digital Services and
Regional Operations Division - West Coast Region

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Executive Summary

This report presents the results of the Regional Framework for Nature Based Solutions in Southwest BC: CWHxm1 Terrestrial Ecosystem Mapping (TEM) – Southern Comox Valley Regional District (CVRD) (BAPID 6641). This project is a joint initiative with Ministry of Land, Water and Resource Stewardship (LWRS), the BC Conservation Foundation (BCCF) and the Coastal Douglas-fir Conservation Partnership (CDFCP). The overall goal for this initiative is to develop a seamless TEM product of the extent of the Coastal Western Hemlock, eastern very dry maritime (CWHxm1) biogeoclimatic unit on Vancouver Island to current TEM standards (RIC 1998 and RISC 2015).

The portion of the CWHxm1 project area mapped in this phase of the project occurs on Vancouver Island, British Columbia (BC) within the CVRD. Specifically, the area is situated south of the Puntledge River and has a total mapped area of 33,274.88 hectares (ha). The project area is located entirely within the CWHxm1. Ecosystem mapping was completed using stereo imagery (3D) in Summit Lite with ArcGIS at a scale of 1:10,000. Mapping followed the appropriate provincial standards and methods (RIC 1998; RISC 2015). The only variance from the TEM standards was the adjustment in the field sampling ratio. This variance was approved by LWRS as documented in the Project Plan.

Field verification of the map product was completed in March and April of 2022. Field sampling was distributed across the project area, on a wide range of ecosystems and site conditions. A total of 120 plots were collected during field verification in 119 polygons. This resulted in a polygon survey intensity of 6.6% of the final map product. This percent of sampling is classified in the TEM standards as Survey Intensity Level (SIL) 5; 5-14%. The field sampling and resulting linework edits resulted in a total of 1,806 polygons in the final TEM product.

Based on the final linework, the average polygon size was 18.42 ha (1,806 polygons covering 33,274.88 ha). Forested ecosystems were the most common throughout the project area covering 23,846.17 ha (71.66%). Non-forested ecosystems, including sparsely vegetated ecosystems, occur on 28.34% (9,428.71 ha) of the project area.

Completion of this mapping expands the seamless coverage of fully attributed (ecosystem and bioterrain information) TEM to current provincial standards for the CWHxm1 on Vancouver Island by 12%; bringing the completed coverage to 34%.

Acknowledgements

Madrone Environmental Services Ltd. (Madrone) would like to thank the Coastal Douglas-fir Conservation Partnership (CDFCP) and the BC Conservation Foundation (BCCF) for the opportunity to complete this project under the direction of Jackie Churchill, Darryn McConkey and Mike Stefanyk from the Ministry of Land, Water and Resource Stewardship (LWRS) and Heather Klassen from the Ministry of Forests (MOF).

Field work was carried out between March 28th and April 8th 2022 by Jennifer McEwen, Jessica Stewart, Harry Williams and Amanda Girard of Madrone.

Ecosystem attribution was completed by Harry Williams, R.P.Bio., P.Ag., and Jennifer McEwen, R.P.Bio. Bioterrain attribution was completed by Jeremy Werbowski, G.I.T., Seanna Zintel, G.I.T., Carolina Costa-Giomi, G.I.T., A.Ag., Amanda Girard, R.P.Bio., R.P.F., Roberta Adams, P.Geo. and Jessica Stewart, P.Geo., P.Ag. with internal QA by Roberta Adams. GIS data management and topology checks were conducted by Anna Jeffries, ADGISA.

Jennifer McEwen was the project manager for the ecological content, mapping and field verification methods, budget tracking, internal QA of the linework and attribution (database), and client communications.

List of Acronyms

Acronym	Description
A.Ag.	Articling Agrologist, registered with British Columbia Institute of Agrologists (BCIA)
ArcGIS	ESRI's Geographic Information System version 10.7
BAPID	Business Area Project IDentification
BC	British Columbia
BEC	Biogeoclimatic Ecosystem Classification
BGC	Biogeoclimatic
BP	Years Before Present
CDFmm	Coastal Douglas-fir, moist maritime biogeoclimatic subzone
CVRD	Comox Valley Regional District
CWH	Coastal Western Hemlock biogeoclimatic zone
CWHxm1	Coastal Western Hemlock, Eastern very dry maritime subzone
dbh	diameter at breast height
DEM	Digital Elevation Model
FAS	Forest Attribute Score
FSR	Forest Service Roads
FWA	Fresh Water Atlas
GIS	Geographic Information System
G.I.T.	Geoscientist In Training, registered with Engineers and Geoscientists BC (EGBC)
ha	Hectares
LMH	Land Management Handbook
LMH25	Land Management Handbook #25 – Field Manual for Describing Terrestrial Ecosystems – 2nd Edition
LMH28	Land Management Handbook #28 – A Field Guide for Site Identification and Interpretation for the Vancouver Forest Region
LMH52	Land Management Handbook #52 – Wetlands of British Columbia: A Guide to Identification
LMH72	Land Management Handbook #72 – Guidelines to support implementation of the Great Bear Rainforest Order with respect to Old Forest and Listed Plant Communities
LWRS	Ministry of Land, Water and Resource Stewardship
m	Metres
nBEC	non-forested Biogeoclimatic Ecosystem Classification
P.Ag.	Professional Agrologist, registered with British Columbia Institute of Agrologists (BCIA)
P.Geo.	Professional Geoscientist, registered with Engineers and Geoscientists BC (EGBC)
QA	Quality Assurance
RISC	Resource Information Standards Committee
R.P.Bio.	Registered Professional Biologist, registered with the College of Applied Biology

Acronym	Description
R.P.F.	Registered Professional Forester, registered with the Association of BC Forest Professionals
SIL	Survey Intensity Level
TEIS	Terrestrial Ecosystem Information System
TEM	Terrestrial Ecosystem Mapping
TR068	Technical Report 068 – Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in British Columbia
TRIM	Terrain Resource Information Management
VOT	Veteran Overstorey Tree
VRI	Vegetation Resource Inventory
WCR	West Coast Natural Resource Region of LWRS

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1 Introduction

The following project report was completed by Madrone Environmental Services Ltd. (Madrone) for the Ministry of Land, Water and Resource Stewardship (LWRS), the BC Conservation Foundation (BCCF) and the Coastal Douglas-fir Conservation Partnership (CDFCP). This report summarizes the steps completed in this phase of the creation of a seamless Terrestrial Ecosystem Mapping (TEM) product for the Coastal Western Hemlock Eastern Very Dry Maritime Subzone Variant (CWHxm1) biogeoclimatic (BGC) unit within the West Coast Natural Resource Region (WCR).

1.1 Project Rationale and Objective

The CWHxm1 ecosystem mapping project (BAPID 6544) is intended to be a multi-year project with the end goal of creating a seamless map product that can be used along with the existing Coastal Douglas-fir Moist Maritime (CDFmm) TEM (BAPID 4522, Madrone 2008) for ecosystem-based management related to Species at Risk (SAR) recovery in Southwest BC. This phase of the project was completed in partnership with the BCCF and CDFCP.

The objective of Phase 1 was to review existing Resource Inventory Standards Committee (RISC) ecosystem mapping products for potential incorporation into the final layer; and complete preliminary bioterrain based ecosystem linework, with no polygon attribution (preliminary linework), within the CWHxm1 of the WCR. The CWHxm1 TEM product from Phase 1 provides seamless delineation of 19,251 ecosystem polygons covering over 264,426.9 ha on Vancouver Island (Madrone 2020). Additional phases of mapping focused on the identification of areas with potential for Garry oak (*Quercus garryana*) ecosystems to occur, field verification, and finalization of the ecosystem mapping for associated polygons (BAPID 6567; Madrone 2021a; Madrone 2021b). These phases of the mapping were incorporated into the BAPID 6544 product.

1.2 CWHxm1 – Biogeoclimatic Ecosystem Classification Unit Summary

The CWHxm1 occurs at lower elevations along the east side of Vancouver Island, on the southernmost islands in the Johnstone Strait, up the south side of the Fraser River, and along the Sunshine Coast, extending north to Desolation Sound (Green and Klinka 1994). The CWHxm1 replaces the CDFmm at sea level at Deep Bay, to as far north as Campbell River. With its geographic position on the eastern slopes of the Vancouver Island Ranges, most of the subzone is east and north-facing, particularly west of Lantzville.

The CWHxm1 can also be found further inland on Vancouver Island along the major valleys between Campbell River and the Cowichan Valley. This subzone is characterized by warm, dry summers and moist, mild winters with little snowfall. Growing seasons are long and often have water deficits on zonal sites. Elevation limits for the CWHxm1 can range from sea level to approximately 450 m in the south but the upper limit can be as low as 150 m near the northern extent of the unit (Green and Klinka 1994).

The final extent of the CWHxm1 in Phase 1 was based on version 11 of BGC linework released in 2018 “BGCv11”, with adjustments based on elevational boundaries within Land Management Handbook 28 (LMH28; Green and Klinka 1994), and discussions with the FOR Research Section Ecologists (Heather Klassen and Sari Saunders). Although the CWHxm1 extends onto the mainland coast, the CWHxm1 TEM (BAPID 6544) only includes the CWHxm1 unit on eastern Vancouver Island within the WCR (Figure 1).

1.3 CWHxm1 TEM – Southern Comox Valley Regional District Study Area

The study area for the CWHxm1 TEM – Southern Comox Valley Regional District (CVRD) included the area within the CVRD, south of the Puntledge River, covering 30,883.44 ha (Figure 1). This included the Puntledge River and a portion of Comox Lake (2,109.06 ha) and ocean. With the removal of the ocean and other linework edits, the final mapped area was 33,274.88 ha.

Topography within the CWHxm1 TEM – Southern CVRD study area is variable with some mountainous areas in the western portion of the study area surrounded by flat benches with agriculture and urbanized areas. The topography has been heavily influenced by glaciation.

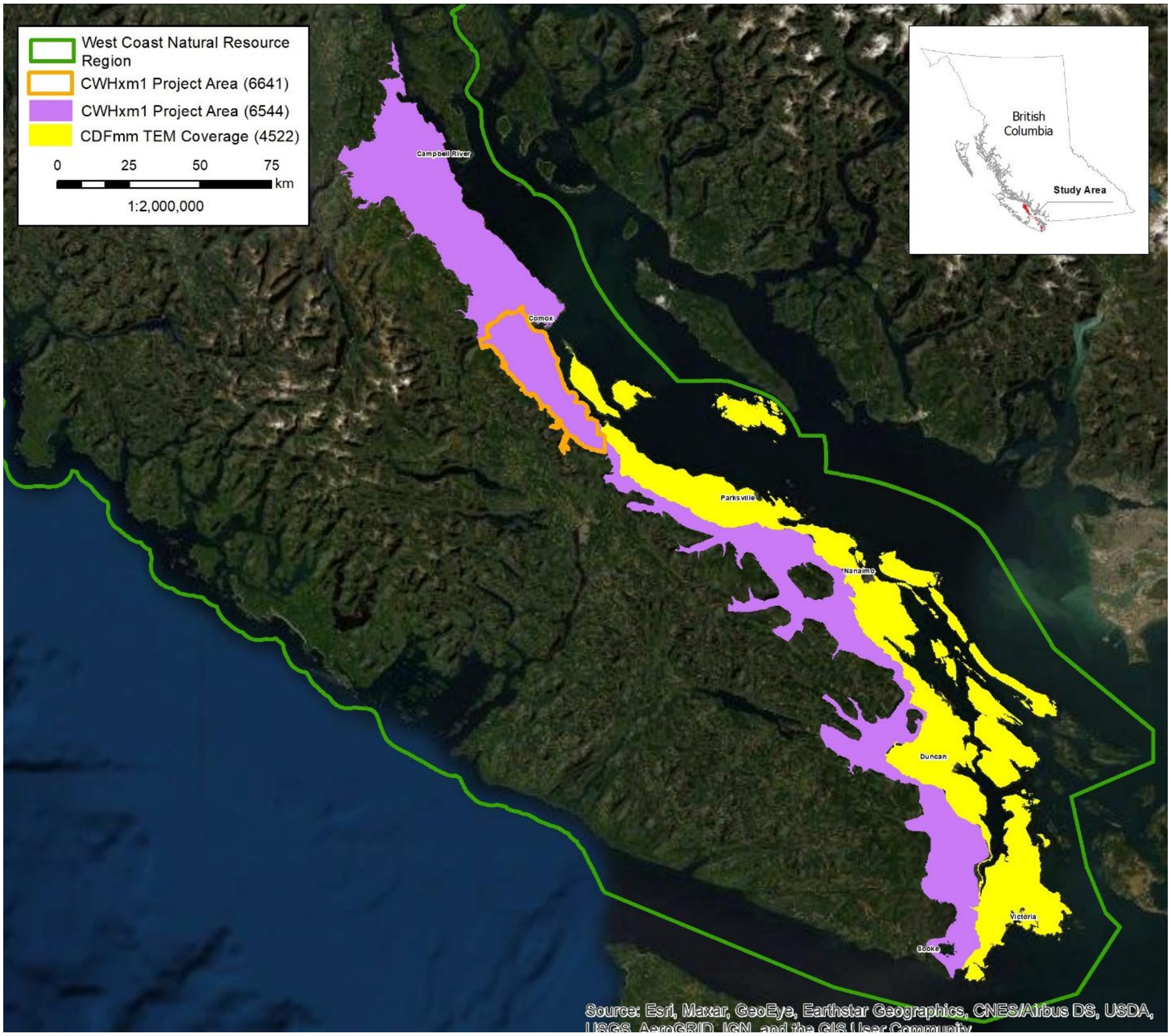

FIGURE 1. Overview of the CWHxm1 mapping from Phase 1 (purple) and adjacent CDFmm TEM (BAPID 4522) in the West Coast Region. The study area for this project (BAPID 6641) is shown in orange outline, within the larger CWHxm1 project area (BAPID 6544).

1.3.1 Physiography of the Study Area

The study area (or ‘project area’) is located in the Nanaimo Lowland, which is the low-lying portion of east Vancouver Island flanked by the Vancouver Island Ranges on its western side (Holland 1976). It roughly spans from Jordan River (west of Victoria) north to the village of Sayward on the northeast coast, and extends westwards into Strait of Georgia, including the Gulf Islands of Denman, Hornby, Gabriola, Galiano, Pender, and Saturna.

The Nanaimo Lowland is predominantly underlain by sedimentary rocks of the Nanaimo Group (discussed further in Bedrock Geology, below), which resulted in differential weathering and erosion creating cuesta-like ridges and valleys (Holland 1976). The ridges are elongated in a northwesterly direction as a result of the differential erosion and are comprised of more resistant conglomerate and sandstone, whereas valleys are comprised of soft rock such as shale and siltstone. Valleys are also present along fault zones.

1.3.2 Bedrock Geology

The bedrock geology of the area was mapped as sedimentary rocks of Upper Cretaceous Age (Massey et al. 1994). These form the Nanaimo Group; rock types include boulder, cobble, and pebble conglomerate, coarse to fine sandstone, siltstone, shale, and coal.

The west margin of the study area is mapped as the Karmutsen Formation of the Vancouver Group; these are basaltic volcanic rocks of Upper Triassic age (Massey et al. 1994). There is also lenses of limestone and tuff associated with this bedrock type. The approximate mapped boundary between the Nanaimo Group and the Karmutsen Formation relative to the study area is the transition to upland at the east shore of Comox Lake and the west margin of Cumberland.

1.3.3 Last Glaciation and Quaternary History

Landforms and surficial deposits in the study area are largely a result of glaciation. The last glaciation in the study area was the Fraser Glaciation; it was well underway on north and central Vancouver Island by 25,200 ± 330 years before present (BP) (Howes 1981). As a result of colder climatic conditions, glaciers grew in both the Coast Mountains and the Vancouver Island Ranges, advancing to the southeast portion of the island via the Strait of Georgia by 19,000 years BP (Alley and Chatwin 1979).

The advancing ice sheet later split into two, forming the Puget lobe (which flowed towards Washington southeast) and the Juan de Fuca lobe (which moved across to the west part of the Vancouver Island). The advance of the ice sheet towards the Vancouver Island resulted in removal and reworking of earlier glacial deposits laid down by the older Cowichan Ice tongue, which originated in the Vancouver Island Ranges (Jungen et al. 1985).

The glacial advance underway by 19,000 years BP was marked by the deposition of a thick sheet of outwash known as the Quadra Sand over isostatically depressed environments ranging from deltaic and shallow marine settings to braidplains (Clague and Ward 2011). Glaciers reached their maximum thickness on central Vancouver Island around 16,000 years BP during the Vashon Stade, when the ice sheet is believed to have completely covered Vancouver Island and flowed southwest across the Juan de Fuca Strait (Alley and Chatwin 1979). More recent work by Hebda et al. (2022) however, hypothesizes that parts of the west coast of northern Vancouver Island were in fact, ice free at this time (16,000-17,500 years BP) and supported a cold, herb-shrub tundra.

An important consequence of the growth of the Cordilleran ice sheet to nearly 2,000 m thick was isostatic depression. The crust was displaced downwards; the effect was greatest near the centre and decreased along the margins of the ice, west of the Coast Mountains and Strait of Georgia (Clague and Ward 2011).

As a result of climate warming and calving of ice at the western margin of the Cordilleran ice sheet, deglaciation began rapidly around 13,000 years BP on Vancouver Island (Clague and Ward 2011). Ice free conditions on Vancouver Island began by 9,500 years BP (Howes 1981). During deglaciation, sea levels on the eastern side of Vancouver Island were high, with the marine limit ranging from 75 m to 175 m above present sea level (Clague et al. 1982). At this time, marine deposits covered glacial till and glaciofluvial deposits to elevations over 100 m above present sea level.

As glaciers retreated from valleys and lowlands, the land isostatically rebounded quickly (uplift) such that sea levels actually dropped below their present day positions in central Vancouver Island. At Comox, there is evidence of now-submerged sand bars that supplied sand dunes with sand during the period of time spanning 8,680 ± 140 to 6,820 ± 200 years BP (Clague et al. 1982).

Isostatic rebound also led to rejuvenation and downcutting by streams. Locally for the study area, this resulted in the creation of narrow but deep box canyons in the lower courses of streams as they approached the ocean (Holland 1976). Local examples of this are the lower courses of the Trent and Tsable Rivers.

1.3.4 Soils

There are three soil surveys that cover the study area; Soils of Vancouver Island, Report No. 44 (Jungen 1985), Soils of the Southeast Vancouver Island: Duncan-Nanaimo Area (Jungen et al. 1985), and Soils of Southeast Vancouver Island: Parksville, Qualicum Beach, Courtenay, and Port Alberni Areas (Jungen et al. 1989). The 1989 soil survey includes 37 individual soils; these expand on the soils classified in the 1985 survey.

Soils in the study area are largely derived from five main parent materials; glacial till, marine sediments, (including glaciomarine), fluvial sediments (including glaciofluvial), colluvial deposits, and organics (Jungen et al. 1985). Till is generally found above elevations of 100 m; below 100 m, marine deposits overlie the till at variable thicknesses. The latter were deposited during periods of marine submergence following deglaciation (as described above in the Quaternary History).

Five soil orders are found in the study area: podzols, brunisols, regosols, gleysols, and organics (Jungen et al. 1985). Brunisols are the most common soil found, having developed from virtually all parent materials described above.

Specifically for the study area, the following soil series (which are outlined in the three soil surveys described above) are predominantly found, divided roughly by main geographical features and villages/town sites:

1. East shore of Comox Lake and Cumberland area:
    a. Quennell Soils (Figure 2), which are Humo-Ferric Podzols that have developed from glaciofluvial parent materials. The Quennell soil is predominantly a rapidly-drained loamy sand;
    b. Quinsam soil, which is also a Huno-Ferric Podzol that developed from glacial till parent materials.

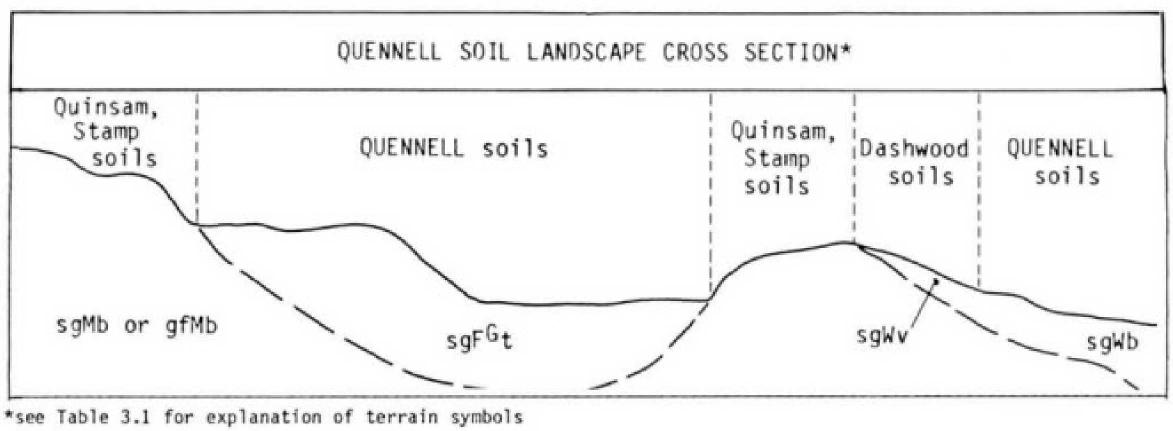

FIGURE 2. The Quennell soil series landscape; this would be similar to an east-west cross-section through the north part of the study area, east of Comox Lake. From Jungen et al. 1989.

2. North of Cumberland and east of Comox Lake, surrounding the Quennell soils:
    a. The Maple Lake and Morrison Creek area is characterized by Metchosin organics, which are very poorly drained Humisols;
    b. Crofton soils, which are Orthic Humic Gleysols that have developed from modern fluvial deposits. These are poorly-drained.
3. Northernmost extent of the study area and east of the Courtenay town site:

a. Kye (Figure 3), Illusion, and Bowser soils, which are all Humo-Ferric Podzols of marine origin. Soil textures in these specific soil types range from loam to sandy loam, and drainage is variable from rapid to imperfect. Other soils that have developed from marine parent materials are present however, they are less common than these three soils;

b. Soils that have developed from glacial tills are less common but still mapped in this area. This include the Quinsam (also Humo-Ferric Podzols, sandy loam) and Royston (Dystic Brunisols, loam) soil series, which are moderately-well to imperfectly-drained loam soils, respectively;

c. There are minor areas of glaciofluvial deposits, and as such, the Quennell and Dashwood (Dystic Brunisols that are moderately-well drained) soils are found. These are found near existing creeks (Millard-Percy Creek zone) and near the Gravel Pit extraction area north of Morrison Creek.

d. A minor unit found in proximity to streams in the northern study area is the Mclean Creek soil, which is a poorly-drained silty clay loam (Gleysol).

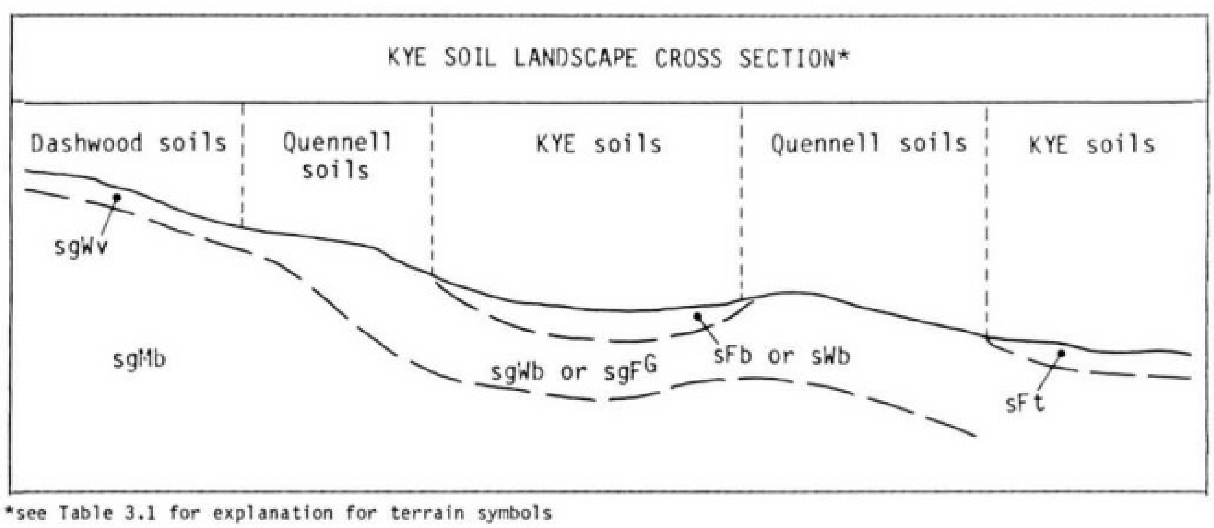

FIGURE 3. The Kye soil series landscape; this is similar to an east-west cross-section through the north part of the study area, west of the Courtenay townsite (Note: No creeks or wetlands are shown but these are present in this area). From Jungen et al. 1989.

4. Marine and till plain and gentle slopes situated approximately east of the Island Highway, extending from Royston to Union Bay:

a. St. Mary (Dystric Brunisol, sandy loam that is imperfectly drained, Figure 4) and Tsolum (Humo-Ferric Podzol, loam that is imperfectly drained) soils of marine parent material origin;

b. Royston and Quinsam soils (till parent materials), of which the Royston soil is the dominant soil;

c. Around the Trent River and smaller streams, there are soils that have developed from modern-day fluvial deposits. These include the Beddis soil series (sand), as well as the Chemainus (Dystric Brunisol, moderately-well drained silt loam) and Crofton soils. The Quennell soil is also mapped around the Trent River.

d. Towards Union Bay and Royston sea-side villages, there is undifferentiated sand mapped around the beach and estuary units.

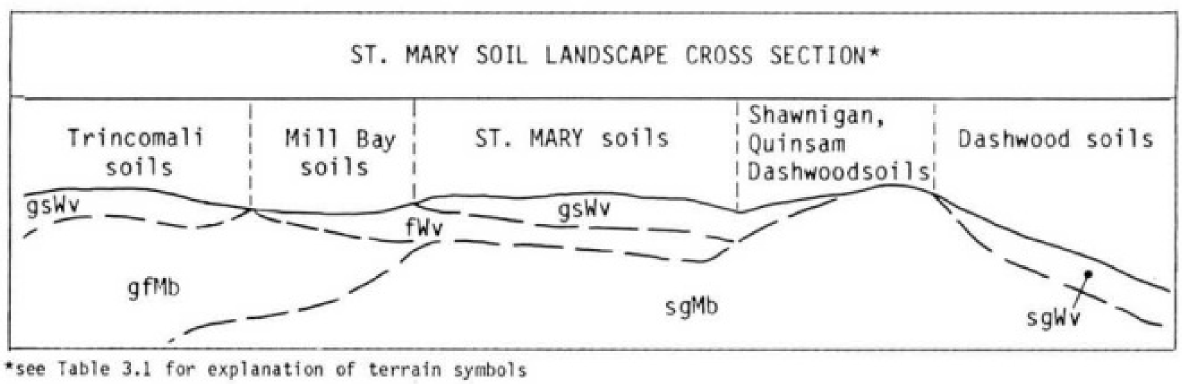

FIGURE 4. The St. Mary soil series landscape; this profile would conform well to the central and southern portions of the study area to the east of the Island Highway. The soils are largely derived from a marine veneer overlying sandy, gravelly glacial till blankets. From Jungen et al. 1989.

5. Southern end of the study area, from Union Bay to Fanny Bay, and east of the Island Highway:

   a. Around the Tsable River, the Beddis soil is mapped in association with the Quennell and Kaptara soils (the latter is a Humic Gleysol of glaciofluvial and marine parent material origin, poorly-drained and considered very minor in extent). The Chemainus soil is also found;

   b. Again, the Royston soil is a dominant unit, as well as the Mexicana soil series (Dystric Brunisol of till parent material origin). Two additional soil series that developed from marine overlying till include the Mill Bay and Trincomali soils, which are both Dystric Brunisols.

6. Western portion of the study area (west of the Island Highway), from south of Comox Lake to the southern terminus of the study area:
    a. Predominantly soils of glacial till parent materials are found. These include the Mexicana (Figure 5), Quinsam, and Royston soils.
    b. Soils that have developed from colluvial deposits are found at the base of the upland mountain ranges on the west terminus of the study area, and are contained in the Soils of Southern Vancouver Island soil survey (Jungen 1985). These include the Holyoak, Robertson, and Rossiter soil series, which are all well to rapidly-drained Humo-Ferric Podzols containing high coarse fragment content (ranging from 20-60%).

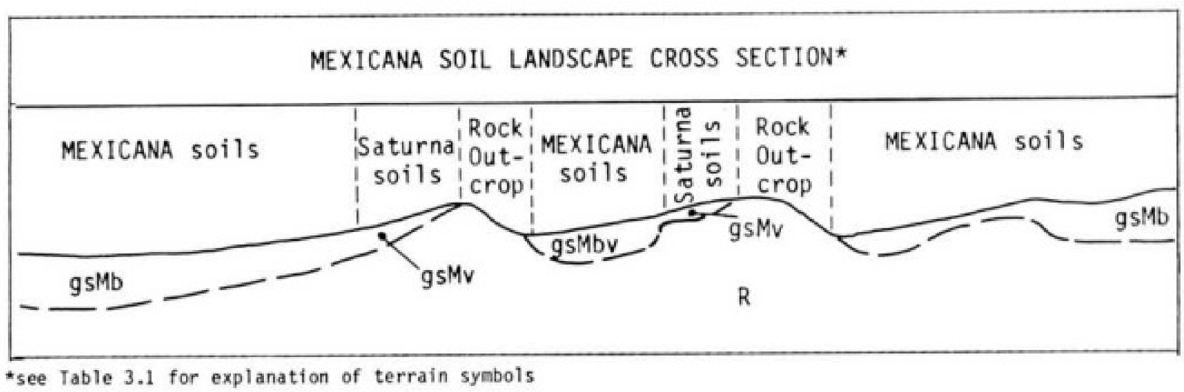

FIGURE 5. The Mexicana soil series landscape; this would conform well to the southern extent of the study area, to the west of the Island Highway. The soils are derived from glacial till parent materials. bedrock outcrops are common. From Jungen et al. 1989.

Overall, based on the review of the soil surveys and compiled mapping in the Soil Information Finder Tool[1], the most frequently encountered soils are Brunisols of glacial till, marine, or marine over glacial till parent material origin. Podzols tend to be limited to the areas where glaciofluvial or marine predominate, or where colluvial deposits are situated at the base of the mountain slopes to the southwest of the study area.

[1] https://www2.gov.bc.ca/gov/content/environment/air-land-water/land/soil/soil-information-finder

2 Methodology

One of the first steps upon initiation of the project was to reference the TEI Ecosystem Mapping Code List (TEI Unit 2022) to determine which ecosystem map units were approved for the CWHxm1, and create the project's working legend with look-up table. The working legend and look-up table provide information for the mappers, gathered from several sources including:

- *Site Identification and Interpretation for the Vancouver Forest Region, Land Management Handbook #28 (LMH28) (Green and Klinka 1994)*
- *Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in BC, Technical Report #68 (TR068) (Mackenzie 2012)*
- *Wetlands of British Columbia: A Guide to Identification (Mackenzie and Moran 2004)*
- *Terrain Classification System for British Columbia. Version 2 (Howes and Kenk 1997)*
- *Field Manual for Describing Terrestrial Ecosystems- 2nd Edition. Land Management Handbook # 25 (LMH25) (BCMFR and BCMOE 2010)*
- *Standard for terrestrial ecosystem mapping in British Columbia. Ecosystems Working Group, Resources Inventory Standards Committee (RIC 1998)*
- *Terrestrial Ecosystem Information (TEI): Ecosystem Mapping Code List. Version 2.1. (TEI Unit 2022)*
- *Terrestrial Ecosystem Information (TEI): Coding Updates for Non-Vegetated, Sparsely Vegetated, and Anthropogenic Units. Version 1.1. (TEI Unit 2020)*

2.1 Project Team

The project team members and their roles and responsibilities for the CWHxm1 TEM – Southern CVRD are summarized in Table 1. The team consisted of a project manager, professional (senior) terrain/bioterrain specialists, professional terrestrial ecosystem ecologist, junior ecosystem and bioterrain mappers and GIS analyst.

TABLE 1. CWHxm1 TEM – Southern Comox Valley Regional District Project Team

Team Member (Madrone)	Role/Responsibility
Tania Tripp	Senior Project Management
Jennifer McEwen	Project Management, Professional Terrestrial Ecosystem Ecologist, Field Crew Member, Reporting, Internal Review and Quality Assurance
Harry Williams	Professional Terrestrial Ecosystem Ecologist, Field Crew Member, Quality Assurance
Roberta Adams	Professional Bioterrain Specialist, Internal Review and Quality Assurance
Jessica Stewart	Professional Bioterrain Specialist, Field Crew Member, Internal Review and Quality Assurance
Amanda Girard	Professional Terrestrial Ecosystem Ecologist, Field Crew Member
Jeremy Werbowski	Junior Bioterrain Mapper
Seanna Zintel	Junior Bioterrain Mapper
Carolina Costa-Giomi	Junior Bioterrain Mapper
Anna Jeffries	GIS Analyst

2.2 Base data and Imagery

The CWHxm1 TEM linework completed in Phase 1 (BAPID 6544, Madrone 2020) and updated in Phases 2 (Madrone 2021a) and Phase 3 (Madrone 2021b) was used for the Southern CVRD TEM. Madrone (2020) describes the input data sources and methods used to create the linework. Table 2 provides a summary of the data sources referenced for the CWHxm1 TEM – Southern CVRD.

TABLE 2. Summary of Data Sources Reviewed for use in the CWHxm1 TEM – Southern CVRD study area

Data	Data Source	Notes
Stereo models (Summit ready files)	FOR	Photos are from 2014 and 2017 and has 90% coverage (no coverage along the western study area boundary)
Orthophotos	FOR	Orthophotos are from 2020 and project area has 65% coverage due to urban area exclusions
Applicable TRIM	DataBC	TRIM was provided for contours, streams, rivers, waterbodies, wetlands, and transportation corridors.
Vegetation Resource Inventory (VRI) 2021	DataBC	Reviewed, found to not cover the entire study area
Geology of the area	DataBC	
Soils Information Finder Tool (SIFT)	DataBC	Reviewed for soils information
BEC (draft)	FOR	BEC draft linework prepared for BAPID 6544 in consultation with FOR/LWRS
FWA Streams, Rivers, Wetlands, Coastline	DataBC	
TEI_Long_Tbl (current)	LWRS	Used TEI_Long_Tbl and associated linework from BAPID 6544 (with updates from BAPID 6567 incorporated)

For polygon attribution, digital images for stereoscopic (3D) viewing were provided on an external hard drive by FOR. These images covered the majority of the study area with a small portion along the western boundary that had no coverage. Imagery available for use in this project is summarized in Table 3.

TABLE 3. Summary of Imagery Available for the CWHxm1 TEM – Southern CVRD study area

Image Year	Percent Coverage	Stereo Imagery	Mapsheets
2014	70%*	Yes	092F065, 092F066,
2017	20%*	Yes	092F055, 092F056, 092F046, 092F047
2020	100%	No	ESRI online Imagery basemap (Service Layer Credit: Maxar)

* please note that the stereo coverage does not add up to 100% due to gaps in coverage.

Edits to the BAPID 6544 TEM linework was completed within ArcGIS 10.7 using Summit Evolution Lite for stereo viewing. The stereo imagery was used for ecosystem attribution with linework done in 2D as in earlier phases. Z values are not supported in the TEIS environment and any original polygons that were created in 3D have lost their Z values after being run through the Contractor Package and readied for standard submission. Due to tight project timelines and increased staff availability working remotely, the 2D imagery (ESRI basemap) was used for bioterrain attribution efficiencies. QA was done using the stereo imagery.

2.3 Incorporation of Existing Ecosystem Mapping

A review of existing ecosystem mapping incorporated into the CWHxm1 TEM from Phase 1 was completed. This included mapping from the Strathcona TSA TEM (BAPID 5437), completed in 2009 by B.A. Blackwell and Associates Ltd. as a NEMNSS[2]. The original map label can be found in the Original Label fields (ORIG_LBL_1, ORIG_LBL_2, ORIG_LBL_3). These contain the decile, site series, site mapcode, modifiers, structural stage, stand composition and disturbance class into a concatenated label for each decile.

Much of the linework and attributes from BAPID 5437 were refined and updated. As the original mapping did not contain structural stages or bioterrain attributes, these were added to ensure a complete final product. The attributes were also reviewed and updated where necessary to reflect the current coding (TEI Unit 2022; Mackenzie 2012). Other edits included linework updates to reflect recent harvesting, or development around Union Bay, and reduce the overall size of the polygons.

[2] NEMNSS – Terrestrial Ecosystem Mapping with no Bioterrain or Structural Stage (RISC 2015)

2.4 Field Assessment

Pre-field research and planning provided the crews with important information regarding access in the study area. Several Forest Service Roads (FSR) and recreational trails were noted throughout the study area. Information regarding their condition and accessibility was gathered and used to plan potential transects for sampling (e.g., what could be accessed by vehicle and where crews would have to sample on foot). The existing roads and trails provided good access and diversity in the ecosystem types. However, most of the private forestry lands west of HWY19A was inaccessible (locked gates). Therefore, plot locations were mostly concentrated in publicly accessible areas.

To meet the standard for a Survey Intensity Level (SIL) 5 the number of polygons visited in the field must be 5-14% of the total number of polygons mapped. The estimated ratio of the field sampling is 75% visual checks, 20% ground plots and 5% full plots. However, a variance was requested from the Province to adjust the ratio to 75% visual checks, 25% ground plots and 0% full plots. This variance was approved by the LWRS and FOR project team as documented in the Project Plan. Table 4 outlines the verification targets based on an initial calculation included in the Project Plan based on the number of polygons in the preliminary TEM product that was field verified. Due to time and budget constraints, this project aimed to achieve SIL 5 at 7%.

TABLE 4. Summary of field verification targets given various sampling intensities based on the preliminary TEM product.

Sampling Intensity	Number of Polygons	Polygons to verify	Ground Plots (25%)	Visuals (75%)
Level 5 (5%)	1,712	89	22	65
Level 5 (7%)		120	30	90
Level 5 (10%)		171	43	128

Data collection in the field followed the standard ecological data collection techniques and methodologies as defined in the Field Manual for Describing Terrestrial Ecosystems (LMH25) (BCMFR and BCMOE 2010). Field crews completed the provincial standard forms for data capture (FS1333 for Ground and Visual plots). The spatial location of each plot was recorded using a handheld GPS unit. For navigation, the crews used an iPad with the Avenza Maps[3] application, which provided the real-time spatial location of crews as well as access to the most recent version of the BAPID 6544 linework (including updates from Phase 3) and suggested sampling locations. Some plot observations were conducted from a distance (*i.e.*, visuals across a landscape). In these cases, the spatial location was collected using Avenza Maps and written on plot cards. Unique

[3] http://www.avenzamaps.com/

polygon IDs were included on plot cards to cross reference the sampling locations. Site photos were taken at all plot locations, including the soil substrates (when examined). The plot and photos were numbered following a standard notation, with the crew lead initials, plot type and plot number (e.g., JMG001 representing Jennifer McEwen, Ground plot, plot 001). Plot sampling aimed to capture a variety of ecosystem types, though access into privately-owned managed forest was limited. Based on the request of the LWRS team, ground plots were collected in floodplain areas, wherever possible.

2.5 Database Completion

The project database used for the CWHxm1 TEM – Southern CVRD was in a TEIS long table format, originally obtained from 2020 Contractor Package (Contractor_Package_20200319)[4]. The long table includes a series of domains (drop-down lists) to assign relevant data to each column (*i.e.*, standardized attribute information assigned to each polygon) (TEI Unit 2020b). On completion of the field sampling, linework adjustments and labels were assigned reflect site observations for each polygon visited each polygon visited.

2.6 Bioterrain Attribution

Bioterrain mapping captures the dominant physical parameters influencing ecological diversity across the landscape. Bioterrain polygon delineation is based on terrain elements: material type and texture, landform (including material thickness, and slope), and geological processes, and soil drainage. Polygon delineation also accounts for other factors that influence ecology such as aspect and slope morphology.

Bioterrain polygons are based on surficial geological features as described in Howes and Kenk (1997). For example:

- Colluvial cones
- Alluvial fans
- Bedrock, at or near surface
- Glacial or modern fluvial deposits
- Till deposits (formerly called morainal)
- Hummocky terrain
- Organic soil (wetlands)
- Major slope breaks

[4] http://www.env.gov.bc.ca/esd/distdata/ecosystems/TEI/ContractorPackage/

Active geological processes influence ecosystem development over time. The bioterrain mapper uses evidence on the imagery and other data sources (e.g., soils mapping) to map materials and processes. These include slope morphology; large surface boulders and blocks; gully morphology; signs of mass movement and erosion; and land use patterns (e.g., gravel pits).

Surface expression provides an indication of material, thickness, and slope. These landforms, in turn, influence rooting depth, the movement of moisture and nutrients through the landscape, and the storage capacity for nutrients and moisture. In addition, the interpretation of landforms provides information on the mode of deposition, the material type, the age of the deposit, the glacial history, and the disturbance history.

Updates to the preliminary linework and labeling were completed at a scale of 1:10,000 within ArcGIS 10.7. Bioterrain labels were applied to the polygons using the provincial standards (Howes and Kenk 1997; BCMFR and BCMOE 2010; RIC 1998) by Seanna Zintel, Carolina Costa-Giomi, Jeremy Werbowski, Roberta Adams, Amanda Girard and Jessica Stewart of Madrone. Conversations between the team members ensured that the observations made in the field were conveyed with the desktop-based mapping team. Field data provided information concerning the surface expression (specifically, the thickness of materials and slope gradients of underlying bedrock) of glacial till, colluvium, and glaciofluvial deposits. Bedrock types, which greatly influence the rates of erosion and weathering of the landscape by glaciers, waves, and streams, were also confirmed by field assessments. Geomorphological processes, if present, were also recorded in the field – these can influence drainage and forest productivity (*i.e.*, debris slides, debris flows, and rockslides).

Linework edits, attribution and internal QA of the attributes were conducted by Roberta Adams and Jessica Stewart. See Appendix II for a list of the terrain codes applied in the CWHxm1 TEM – Southern CVRD.

2.7 Ecosystem Linework and Attribution

On completion of the bioterrain attribution and linework updates, linework updates were made, where required, to capture specific ecological features (e.g., crests, toe slopes, etc.) or create polygons with fewer ecosystem types and/or structural stages. In some cases, this meant that lines were drawn along manmade features (e.g., roads, pipeline corridors) where they were obvious on the imagery.

Each ecosystem polygon was labeled using provincial standards to describe the vegetation, site conditions, structural stage, stand composition, and disturbance (RIC 1998; BCMFR and BCMOE 2010).

Polygons were assigned up to three ecosystem types (components), each comprising a quantified proportion of the polygon area using deciles that add to 10, representing 100% of the polygon. Pure polygons (100% of one ecosystem type) were mapped whenever possible.

Ecosystem mapping for forested site series was based on the 2-digit classification coding and descriptions in the Vancouver Forest Region Field Guide (LMH28) (Green and Klinka 1994). Non-forested, sparsely vegetated/non-vegetated, and anthropogenic units not described in the LMH28 were classified following the modified BC correlated TEM code list (TEI Unit 2020a) using two upper case letters, or the nBEC's two-letter Group/Realm and class classification system (TR068, Mackenzie 2012). Floodplain units with a structural stage of 4 or greater are mapped as the appropriate numbered site series from LMH28, where applicable. When these units are in a shrub (3a/3b) structural stage, or when there is no corresponding site series, they are attributed based on the classification in TR068 (e.g., Fm for mid-bench floodplain units). Wetlands mapped in the study area that could not be identified to the site association level described in LMH52 (Mackenzie and Moran 2004) and were classified using the generic two letter coding from TR068 (e.g., Wm for wetland marsh) (See Appendix I for a list of the ecosystem units mapped).

2.7.1 Site Modifiers

As described in the 1998 TEM standards, site modifiers (a set of descriptive terms for certain site conditions) are used to describe conditions specific to an ecosystem (RIC 1998). For example, if a site series happens to occur on a warm or cool aspect, a warm (w) or cool (k) modifier code will be applied in the data base. In addition to those noted above, for the CWHxm1 TEM – Southern CVRD study area, site modifiers have been applied to indicate active floodplain, hummocky terrain, gentle slopes, ridges, gullies, terraces, coarse and shallow soils. Ecosystem site modifiers applied in the mapping are provided in Appendix II.

2.7.2 Structural Stages

A numerical structural stage designation (1 through 6, indicating sparse/cryptogram through mature forest) was assigned to each mapped ecosystem, except for units that do not require one (e.g., pond). A structural stage modifier (a single lower-case letter) further characterizes the structural stages. Structural stage designations and modifiers follow current standards (BCMFR and BCMOE 2010) and are defined in Appendix II.

2.7.3 Stand Composition

A stand composition (appearance) modifier (single upper-case letter) is used to differentiate forest stands (structural stages greater than 4) based on whether they are dominated by conifers (C), broad-leafed trees (B), or mixed (M) (Appendix II). Forested ecosystems were classified as coniferous or broadleaf when 75% or greater of the stand consisted of coniferous or deciduous tree species, respectively. The mixed stand modifier was assigned when neither the coniferous nor deciduous tree species were dominant.

2.7.4 nBEC Coding and Cross-walk (Look-Up) Table

Non-forested BEC units (nBEC) have standardized hierarchy of coding and are described in Biogeoclimatic ecosystem classification of non-forested ecosystems in British Columbia (Mackenzie 2012). Coding follows the TEI Ecosystem Mapping Code List (TEI Unit 2022) for each of the mapped units.

Within the hierarchy of nBEC, Realm is the broadest level of distinction. It delineates major biotic types that reflect gross differences in water abundance, quality, and source. Group is next and designates a broad association of functionally similar ecosystems within a Realm. Ecologically relevant environmental features that have a dominant influence on ecosystem structure are used to differentiate between Groups, such as Terrestrial (T) and Freshwater (O) Groups. The nBEC 'Class' is next, which is a refined division of the Realm reflecting ecosystems that have broadly similar vegetation physiognomy, hydrology, and water quality (Mackenzie 2012).

As part of this mapping project, the fields for Realm, Group, and Class (R/G/C) were populated into the TEM database for each of the polygons mapped in the CWHxm1 TEM – Southern CVRD. Completion of this was done via a cross-walk table (referred to in scripting as a "look-up" table). A Python script was created and applied that 'reads' the mapcodes in each decile and 'looks-up' the associated nBEC codes and populates the associated TEIS database fields. Attribution of the nBEC fields in the TEM database enable users of this product to 'roll-up' similar ecosystem features. For example, to identify all polygons that contain a Rock Group.

The attribute table also included KIND as a User Defined Field, which reflects the "kind of surface material". The values include Mineral (M), Organic (O), True Non-soil (N), and Unclassified (U) and have been defined by the Canadian Soil Information Service[5]. The nBEC and KIND codes are defined in Appendix II.

2.7.5 Polygon Size

TEM standards specify a minimum polygon size of 1 ha for a 1:10,000 scale TEM product (RISC 2015). However, a minimum polygon size of 0.5 ha, or smaller, is appropriate for the 1:10,000 scale to capture biologically important features. Smaller polygons that capture important features, such as small wetland features or remnant patches of old forest are preferred over being included as 10% of a larger polygon.

2.8 Quality Assurance

Internal Quality Assurance (QA) of the bioterrain mapping was conducted by Roberta Adams and Jessica Stewart. A thorough final internal QA was completed by Jennifer McEwen to capture and

[5] https://sis.agr.gc.ca/cansis/nsdb/soil/v2/snt/kind.html

change any errors in the database. Upon review of the draft product by LWRS, additional QA feedback was addressed and incorporated into the final product.

The final GIS product represents a seamless digital feature class with corresponding attributes for each polygon. Polygon cleaning (*i.e.*, topology) and map production was conducted by Madrone's in-house digital mapping department (*i.e.*, Anna Jeffries) who prepared the final files to meet provincial standards and for delivery to the Ministry in ArcMap compatible format. The spatial databases are in accordance with the current *Terrestrial Ecosystem Information Digital Data Submission Standard – Draft for Field Testing (Database and GIS Data Standards)* (RISC 2015).

The TEM product contains the polygons with the corresponding digital polygon attribute database, including all core TEM attributes (Appendix II). Additional polygon attributes, including KIND, were included as User Defined tables in the project geodatabase. Each feature within the spatial data has an appropriate feature code and a unique identifier (POLYPROJID) linking spatial features to the attribute database(s). The only variance from the TEM standards was the adjustment in the field sampling ratio. This variance was approved by the LWRS and FOR project team as documented in the Project Plan.

2.9 Final Products

All final deliverables were submitted in accordance with current RISC and Terrestrial Ecosystem Information Standard (TEIS) Digital Data Submission standards (RISC 2015) using the 2020 Contractor Package (TEI Unit 2020b). The following is a list of the deliverables:

- Project Plan (tem_6641_pp.pdf)
- Digital data submission of the updated TEM linework as a digital product (*i.e.*, TEIS polygons long-table format as per current digital data submission standards (RISC 2015) (as provided in the 2020 contractor package) (TEI_Long_Tbl, TEI_Sample_Site_Points, TEI_Project_Details, TEI_Usr_Dfn_Data, TEI_Usr_Dfn_Fields in Operational_Data_6641.gdb, and TEI_Long_Tbl in Operational_Data_6544.gdb)
- Field data including photos and scanned plot cards (tem_6641_eci.zip)
- Project report outlining applied methods and results for the CWHxm1 - Southern CVRD ecosystem mapping product (this report – tem_6641_rpt.pdf)
- Working Legend and Look-up Table (tem_6641_wl.xls)
- Signed Project Completion Certificate (tem_6641_cert.pdf)

All project deliverables are signed-off by a Registered Professional Biologist, a Professional Geoscientist and a GIS Analyst.

3 Results

A total of 1,806 polygons were delineated in the CWHxm1 TEM – Southern CVRD product, covering 33,274.88 ha, resulting in an average polygon size of 18.42 ha (Table 5).

TABLE 5. Average polygon size within the CWHxm1 TEM – Southern CVRD

	Ecosystem Mapping Coverage (ha)	# Polygons	Overall Polygon Size (ha)
Average Overall Polygon Size (ha)	33,274.88	1,806	18.42

Due to the urban and rural development at lower elevations, larger terrestrial polygons were mapped in the flat areas. These areas included the City of Courtenay, Village of Cumberland and smaller communities of Royston, Union Bay and Fanny Bay. The largest polygon is Comox Lake (2,109.06 ha) and the smallest is a fen (0.17 ha). Some of the largest polygons in the mapping area include rural residential, urban, industry, cultivated fields and ocean. It's worth noting that much of the study area west of the Inland Island Highway (HWY 19A) has also been heavily impacted by harvesting, making it difficult to create smaller polygons.

3.1 Field Sampling

Field verification of the preliminary map product (1,712 polygons) was completed from March 28th to March 31st and April 5th to April 8th, 2022 (refer to Table 3 for a list of field crew members). Field verification sites were limited to areas accessible by road and trail.

A total of 120 plots were collected in the field within 119 distinct polygons. Further refinement to the mapping post-field was required, resulting in a total of 1,806 polygons. A summary of the sampling goals for the target 7% verification based on the pre- and post-field polygon count and the number of plots per sampling type is provided in Table 6. Figure 6 shows the ecosystem linework and the distribution of field sampling plots within the study area.

TABLE 6. Final Plot Sampling Summary for the CWHxm1 TEM – Southern CVRD

	Ground Plots	Visual Checks	Plot Total
Requirements for SIL5	25%	75%	100%
Minimum plot counts for SIL 5* (7%)	30	90	120
Minimum plot counts for SIL 5 (7%)**	32	94	126
Madrone Plots			
Total Plots	30	90	120
Percentage of Total Plots Collected	25%	75%	100%

*based on the preliminary linework (1,712 polygons)
**based on the final linework (1,806 polygons)

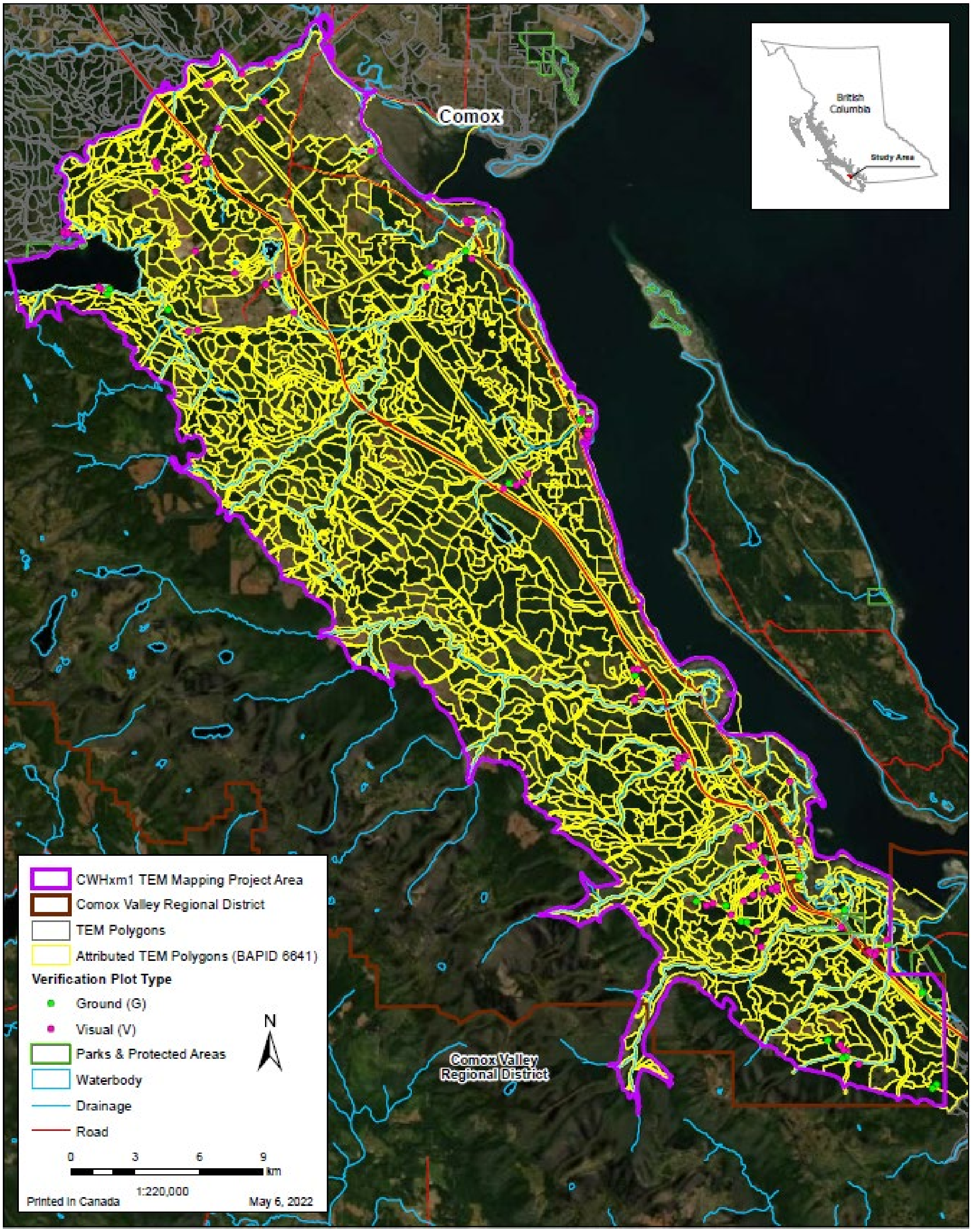

FIGURE 6. CWHxm1 TEM - Southern CVRD Polygon Field Verification Coverage Based on Final Linework

Based on the preliminary (pre-field) linework, Madrone's field sampling efforts met the 7.0% targets for both ground and visual plots (SIL 5). Verification based on the final linework was 6.6% (Table 7).

TABLE 7. Survey Intensity Level based on field verification of pre- and post-field polygon linework

Polygons in Preliminary Mapping	Plots Collected	Verification (%)	Survey Intensity Level (SIL)	Polygons in Final Mapping	Polygons Verified	Verification (%)	Survey Intensity Level (SIL)
1,712	120	7.00	5 (5-14%)	1,806	119	6.59	5 (5-14%)

3.2 Forested Ecosystems

Forested ecosystems represented the majority of the landscape, covering 71.66% (23,846.17 ha) of the total mapped area. The most common tree species in the study area are the western hemlock (*Tsuga heterophylla*) and Douglas-fir (*Pseudotsuga menziesii*), with western redcedar (*Thuja plicata*), grand fir (*Abies grandis*) and Sitka spruce (*Picea sitchensis*) also occurring. Deciduous trees are most common at lower elevations and in areas of recent disturbance. These include red alder (*Alnus rubra*), and bigleaf maple (*Acer macrophyllum*) with black cottonwood (*Populus trichocarpa*) found in riparian areas.

The most common forested unit was the mesic zonal Western hemlock – Douglas-fir (HwFd) – *Kindbergia* (01) occurring over 41.66% of the southern CVRD mapping area. The second most common forested unit was the Western redcedar – sword fern (05) occurring over 14.09% of the study area. All other forested ecosystems ranged between <0.01% - 7.17% of the study area (Table 8).

Trends specific to the ecosystems mapped across the CWHxm1 TEM – Southern CVRD study area included:

- Extensive forestry history throughout this area
- Residential and urban development scattered throughout the eastern half of the study area, east of Highway 19A, from Courtenay to Fanny Bay. The exception to this is Cumberland, located west of Highway 19A near Courtenay.

TABLE 8. Forested Ecosystems Mapped in CWHxm1 TEM – Southern CVRD

Site Series	Ecosystem name[6]	Area (ha)	% of Area Mapped
01	HwFd – Kindbergia	13,861.70	41.66%
02	FdPl – Cladina	112.10	0.34%
03	FdHw – Salal	619.50	1.86%
04	Fd – Sword fern	178.65	0.54%
05	Cw – Sword fern	4,688.73	14.09%
06	HwCw – Deer fern	786.76	2.36%
07	Cw – Foamflower	2,384.58	7.17%
08	Ss – Salmonberry	263.47	0.79%
09	Act – Red-osier dogwood	399.59	1.20%
11	Pl - Sphagnum	8.97	0.03%
12	CwSs - Skunk cabbage	136.29	0.41%
13	Cw - Salmonberry	229.86	0.69%
15	Cw - Slough sedge	175.02	0.53%
00 (AM)	Ra – Manzanita	0.94	<0.01%
Total Area within the CWHxm1 TEM – Southern CVRD		**23,846.17**	**71.66%**

3.3 Non-forested Ecosystems

The following results summarize the non-forested ecosystems mapped in the CWHxm1 TEM – Southern CVRD study area. Non-forested ecosystems, including sparsely vegetated ecosystems, anthropogenic units, and wetlands, represented 28.34% (9,428.71 ha) of the project area mapped. If anthropogenic units are excluded, non-forested ecosystems represent 13.46% (4,477.56 ha) of the study area (Table 9).

Comox Lake was the largest open water unit at 2,109.06 ha. Other lakes and ponds accounted for 80.45 ha combined. River and floodplain units, including the Puntledge and Trent Rivers and other smaller riparian units accounted for 0.52% (172.96 ha) of the study area combined (Table 9). Wetland ecosystems, including bog, fen, marsh, swamp and shallow water represented 1.49% (494.80 ha) of the total area mapped. However, it's worth noting that many of the floodplain and wetland areas were forested. If the forested and non-forested floodplain units were combined, the total floodplains mapped is 2.51% (836.03 ha) of the study area. Similarly, the non-forested and forested wetland combined make up 3.14% (1,044.95 ha) of the study area. The Morrison Creek wetland complex was the most extensive in the area, located north of Cumberland, west of Highway 19A.

[6] https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh28.htm

Beach and estuarine units were mapped along the eastern boundary of the study area. These units combined accounted for 4.72% (1,569.26 ha).

Rock (Ro) and talus (Rt) were rare in the study area, accounting for only 0.15% (51.02 ha) of the study area.

TABLE 9. Non-forested Ecosystems Mapped within the CWHxm1 TEM – Southern CVRD

Ecosystem Unit	Total (ha)	% of Area Mapped
Bb (Beachland)	184.64	0.55%
Ed (Estuary meadow)	14.68	0.04%
Ed01 (Tufted hairgrass - Meadow barley)	23.97	0.07%
Ed02 (Tufted hairgrass - Douglas' aster)	115.78	0.35%
Em (Estuary marsh)	2.90	0.01%
Em01 (Widgeon-grass)	75.23	0.23%
Et (Estuary tidal flat)	1152.06	3.46%
Fa (Active fluvial – gravel bars)	65.69	0.20%
Fl (Low-bench floodplain)	43.64	0.13%
LA (Lake)	2,132.17	6.41%
PD (Pond)	57.34	0.17%
RI (River)	63.64	0.19%
Ro (Rock Outcrop)	50.64	0.15%
Rt (Rock Talus)	0.38	<0.01%
Wb (Wetland bog)	2.77	0.01%
Wf (Wetland fen)	94.34	0.28%
Wf51 (Sitka sedge - Peat-moss)	21.05	0.06%
Wm (Wetland marsh)	26.97	0.08%
Wm05 (Cattail marsh)	12.22	0.04%
Ws (Wetland swamp)	191.88	0.58%
Ws50 (Hardhack - Sitka sedge)	33.67	0.10%
Ws51 (Sitka willow - Pacific willow - Skunk cabbage)	0.41	<0.01%
Ww (Shallow water wetland)	111.49	0.34%
Total Non-forested Units (excl. Anthropogenic)	**4,477.56**	**13.46%**

Several anthropogenic non-forested or sparsely-vegetated units were mapped in the study area, including Cultivated Field (CF), Corridor/Industry-related Disturbance (CX), Hydroelectric Dam (DZ), Exposed Soil (ES), Gravel Pit (GP), Mine Spoil (MS), Reclaimed Mine (RM), Road Permanent (RP), Rural Residential (RR), Urban (UR) (Table 10) . These combined accounted for 4,951.15 ha, or 14.88% of the study area.

TABLE 10. Anthropogenic Units Mapped within the CWHxm1 TEM – Southern CVRD

Ecosystem Unit	Total (ha)	% of Area Mapped
CF (Cultivated Fields)	521.26	1.57%
CX (Corridor/Industry Disturbance)	633.36	1.90%
DZ (Dam)	10.74	0.03%
ES (Exposed Soils)	0.57	<0.01%
GP (Gravel Pit)	140.29	0.42%
MS (Mine Spoil)	4.33	0.01%
RM (Reclaimed Mine)	7.56	0.02%
RP (Road Permanent)	369.02	1.11%
RR (Rural Residential)	2,080.55	6.25%
UR (Urban)	1,183.47	3.56%
Totals	**4,951.15**	**14.88%**

3.4 Structural Stages

Evidence of logging can be seen throughout the CWHxm1 TEM – Southern CVRD study area with most of the logged areas represented by Structural stage 3 (shrub/herb; 0-20 years since disturbance) or 4 (pole/sapling; 20-40 years since disturbance), occurring over 5,364.45 ha and 7,770.34 ha, respectively. Structural stage 5 (indicative of young forests; 40-80 years since disturbance) occurs over 8,272.70 ha; representing 24.86% of the total mapped area. Polygons that were not field verified had structural stage values assigned based on the 3D imagery.

Mature forest (structural stage 6; 80-250 years) accounted for 7.32% (2,436.68 ha) of the area mapped. No old forest was mapped in this project area. It is possible that other small patches do exist in the study area, but they were not encountered during the field sampling and were not obvious in the interpretation of imagery. If old forest is likely to occur anywhere, it would likely be on steep slopes south of Comox Lake and in riparian gullies. Table 11 provides a summary of the structural stages mapped in the study area.

TABLE 11. Summary of structural stages mapped within the CWHxm1 TEM – Southern CVRD

Structural Stage	Total (ha)	% of Area Mapped
0	6,086.59	18.29%
1	187.75	0.56%
1a	1,457.40	4.38%
2	2.95	0.01%
2a	153.53	0.46%
2b	732.23	2.20%
2c	105.32	0.32%
3*	5,364.45	16.12%
3a	574.87	1.73%
3b	130.07	0.39%
4*	7,770.34	23.35%
5*	8,272.70	24.86%
6*	2,436.68	7.32%
Totals	**33,274.88**	**100.00%**

*Structural stages associated with forested sites

3.5 Disturbance

Logging is the most common type of forest disturbance observed in the mapping area. A total of 832 polygons were noted with logging ("L") as a disturbance type for one of the ecosystems mapped, though it is important to note that this disturbance type was typically only assigned when logging has occurred within the past 40 years (e.g., structural stage and 4). Active forestry roads were noted throughout the area with evidence of recent harvesting throughout. Other disturbances noted were due to recreation (camping and trails), soil modification, terrain and water. A list of disturbance codes can be found in Appendix II.

3.6 Bioterrain

The breakdown of bioterrain types by genetic material as observed and mapped in the study area is summarized in Table 12.

TABLE 12. Surficial Material of Bioterrain Types Mapped in the TEM Study Area

Surficial Material	Total Area (ha)	Study Area Proportion (%)
Anthropogenic (A)	2,343.69	7.04%
Colluvium (C)	151.10	0.45%
Fluvial (F) (active and inactive)	1,886.39	5.67%
Glaciofluvial (FG)	1,379.76	4.15%
Lacustrine (L)	9.50	0.03%
Glaciolacustrine (LG)	29.57	0.09%
Till (M)	13,743.04	41.30%
Not Classified (N)	2,223.62	6.68%
Organic (O)	577.92	1.74%
Bedrock (R)	66.95	0.20%
Marine (W)	10,447.87	31.40%
Glaciomarine (WG)	415.46	1.25%
TOTAL	**33,274.88**	**100%**

3.6.1 Dominant Bioterrain Types

Glacial till (M) is the most common bioterrain type in the study area, at 41.30%. The surface expression of the till ranges from blanket to thin veneer, generally becoming thinner as one proceeds to the west margin of the study area. An exception is near the southeast shore of Comox Lake, where exposures reveal a deep (over 2m thick) deposit of sandy, gravelly till (Photo 1).

PHOTO 1. Glacial till blanket exposed near the southeast shore of Comox Lake.

Field access to the west side of the study area in the approximate north half was limited due to active forestry operations and closed forest roads. The west side of the study area could be considered the portion of terrain falling on the west side of the island highway. There is predominantly till, as well as moderate (27-49%) to moderately-steep (50-70%) slopes, colluvium, and near-surface bedrock in the approximate center of the study area north of the Tsable River, and along the west margin of the southern portion of the study area where the Vancouver Island Ranges begin (Photo 2).

PHOTO 2. Gentle till slope situated at the base of steeper terrain in the southernmost portion of the study area near Cook and Chef Creeks (plot HWG001). The Douglas-fir stand is 45-50 years old and has a soil moisture regime and soil nutrient regime of 4B.

These areas in general were not the focus of the field assessments (which focused on floodplains) but there are plots where the till abuts steeper terrain in these areas (e.g. HWG001).

The second most common bioterrain type is Marine (W) deposits (31.40%). As described in Section 1.3.3., the Courtenay-Comox area was inundated by marine waters following deglaciation of Vancouver Island by the start of the Holocene epoch. The marine deposits, which include deltaic and shoreline deposits of sand, pebbles, and cobbles, cloaked the land to elevations of approximately 100 m above sea level. There is a separate bioterrain code for glaciomarine (WG) deposits, which were deposited in a combined marine and glacial ice setting and can include silt and clay.

Distinguishing between a sandy glacial till and marine deposits in the field is difficult where the marine deposits are veneered (<1 m) or thinly veneered (<20 cm) over the till. The marine deposits tend to contain a coarse-grained sand and rounded to subrounded pebbles and cobbles, whereas the till contains a higher proportion of fine to medium-grained sand, silt, and minor clay. Coarse marine deposits (pebbles, cobbles) can also be confused with glaciofluvial if they have been excavated and moved to facilitate road construction and/or forestry developments (Photo 3).

PHOTO 3. Excavated marine deposits (to facilitate road construction for timber harvest) at plot JMG043, located just off McCleod road to the west of Union Bay. The elevation of this site is ~115 m above sea level.

Anthropogenic (A) deposits comprise 7.04% of the study area. Anthropogenic units consist of paved roads (including highways, transmission line right-of-ways), landfills, large areas of residential/commercial development around Courtenay and Comox, quarry operations (of glaciofluvial material), old mine tailings sites (near Union Bay, Photo 4) and other areas of impervious surfaces of substantial size (*i.e.*, subdivisions, parking lots).

PHOTO 4. Coal waste piles at Union Bay - this forms a blanket of anthropogenic materials over Nanaimo Group bedrock and a thin veneer of marine deposits.

Areas were observed where imported fill has been brought in advance of residential development in proximity to the marine foreshore. Although the volume of fill is substantial in some cases, it generally comprises a small percentage of the polygon such that it would be a third decile. Where fill was observed, there is a veneer of marine deposits overlying sedimentary bedrock.

3.6.2 Additional Bioterrain Types

Not classified (N) is a minor unit comprising 6.68% of the TEM study area. These are mapped around small ponds that do not meet the Lacustrine (L) definition of Howes and Kenk (1997), which is applied to Holocene lake basins that have either drained or infilled (e.g. modern beach along a lakeshore).

Fluvial (active and inactive, F) materials comprise 5.67% of the TEM study area. They are found throughout the study area, around the major rivers (Puntledge, Trent, Tsable) and creeks (Millard-Piercy, Morrison, Hart, Wildred, Rosewall, and Cook). The most extensive fluvial deposits were observed along the Puntledge River (Photo 5) and Trent River (Photo 6).

PHOTO 6. Riverbank of the Puntledge River showing sand, pebbles, cobbles, and boulders.

PHOTO 5. Cottonwood and maple dominated floodplain situated adjacent to the Trent River near the Train Trestle Bridge. The floodplain is comprised of fluvial deposits. Adjacent to the floodplain, there are exposures of Nanaimo Group sedimentary rock, which includes thick bands of coal.

The most common fluvial surface expressions in this area are plain and terrace. There are also fluvial plains that mingle with marine deposits where these creeks flow into the ocean. Where the water is stagnant or slow-moving, sediment is not carried away. This results in the formation of a delta. Good examples of this are the Trent River estuary at Royston or where the Tsable River flows into Fanny Bay. Smaller fluvial plains (deltas) are present where Hart Creek flows into Union Bay and Wilfred Creek flows into Mud Bay (Photo 7).

PHOTO 7. Wilfred Creek fluvial plain (delta) at Mud Bay. This is plot HWV010.

Glaciofluvial (FG) comprises approximately 4.15% of the study area, primarily in the northern portion. It is clustered to the east of Comox Lake, between Bevan Road and Comox Lake Road. There are also deposits observed north and west of the Cumberland townsite. An excellent exposure of glaciofluvial deposits was observed in the Cumberland Community Forest (specifically, Coal Creek Historic Park near Perseverance Creek) in an upland area adjacent to a cluster of wetlands (Photo 8).

Glaciofluvial deposits mingle with marine and till deposits along Lake Trail Road, which creates a complex mix of parent materials in this area known as Bevan. This made surficial material classification difficult, in particular where this material has been disturbed to facilitate residential, industrial, and forest development.

PHOTO 8. Exposure next to recreational trail that shows glaciofluvial sediments adjacent to a large wetland. This is observed in the Cumberland Community Forest at plot JMG021.

Organic (O) deposits comprise approximately 1.74% of the TEM study area. They are found in association with wetlands in predominantly the north half of the study area, between Trent River (north) and Hart Creek (south). There is also a cluster of wetlands around the east border of the Cumberland townsite, extending north through Morrison Creek to the Puntledge River. The organics in the Morrison Creek

area are humic in composition; there are areas where fluvial deposits flow into the wetlands; these fluvial plains have been separated out from the wetland polygons where sufficiently large (e.g. JMG051, Photo 9).

Glaciomarine (WG) comprises approximately 1.25% of the study area. It was observed along the steep slopes of the Trent River greenway and in low-lying depressions around wetlands (as silty clay deposits – these would be Gleysol parent materials). On the steep south to southeast-facing slope above Trent Creek, a large area affected by recent slump-earthflow was observed above the river (Photo 10).

PHOTO 9. Humic organics observed around a wetland near Morrison Creek; the creek itself forms a meandering plain to the east and was separated from the wetland. This is plot JMG051.

The slump-earthflow has occurred in fine-grained silt and clay that overlies a deep deposit of marine and till deposits (sand, pebbles, cobbles).

Surficial mapping by Fyles (1960) does not show either glaciolacustrine nor glaciomarine mapped along the steep slopes above the Trent River. These deposits did not appear to be bedded; their proximity to the ocean also strongly suggests glaciomarine.

PHOTO 10. Slump-earthflow observed along the steep, south to south-east facing slopes above the Trent River at JMG031. Another larger slump was observed upslope of this area.

Colluvium was not commonly observed in the study area. Colluvium (C)[7] comprises 0.45% in the TEM study area and was primarily observed in the field as a blanket deposit along a steep, north-facing slope on the south side of Comox Lake (plot JMG015, Photo 11). In the southern portion of the study area, it would likely be present on the steep slopes above Wilfred Creek (Mount Curran) and further upslope of the plots near Cook Creek (slopes of Mount Schofield).

PHOTO 12. Colluvial blanket observed on a steep slope south of Comox Lake (plot JMG015). Colluvium is not common due to the low-lying topographic relief over the majority of the study area.

Rock (R) comprises 0.20% of the study area. Bedrock comprised of sedimentary rock conforming to the Nanaimo Group was observed at Union Bay (plot JMV036), outcropping adjacent to the marine foreshore.

Another large outcrop was observed along the Trent River where the trestle bridge is situated next to a broad floodplain. There are thick bands of coal exposed in the bedrock cut made during construction of the bridge. Extensive bedrock outcrops were also observed along the steeper terrain traversed south of Comox Lake (plot JMG015, Photo 12); the bedrock in this area conforms to the basaltic volcanic rock of the Karmutsen Formation mapped by Massey et al. (1994).

PHOTO 11. Karmutsen volcanic bedrock located south of Comox Lake near plot JMG015. Bedrock exposures are not common in the study area.

[7] From Howes and Kenk (1997): “[Colluvium is] Materials that have reached their present positions as a result of direct, gravity–induced movement involving no agent of transportation such as water or ice, although the moving material may have contained water and/or ice”.

Glaciolacustrine (LG) comprises a very small percentage of the study area at 0.09%. From the imagery, it was mapped around Bradley Lake, south of the Trent River and on the west side of the study area. Another area of glaciolacustrine was mapped east of Comox Lake, where a depression is situated inland from Whyte's Bay. Glaciolacustrine was not observed in the field assessments.

3.6.3 Soil Types

In this TEM study, no full plots were completed but rather, ground and visual plots. Full plots, which are typically excavated to the C horizon, provide more detailed soil information (e.g. soil great group) than ground and visual plots. Regardless, all ground plots include an assessment of the estimated rooting zone depth, rooting zone soil texture, the humus (or organic) form, and texture of the parent materials in addition to the estimated soil moisture regime (SMR) and soil nutrient regime (SNR). From these, the possible soil order can be inferred, as well as general trends in richness and moisture relative to slope position and soil parent material.

The most common soil orders observed from our ground plots are Brunisols, Podzols, Regosols, and Organic soils. The distribution of these is strongly related to the soil parent materials and landscape position. Soils also form associations; these form under similar climatic conditions and are thus of similar age. They also develop from similar parent materials. Specifically for this study area in the Nanaimo Lowland, Brunisols are generally found on the low-lying areas close to the ocean whereas Podzols are situated at the base of the mountain slopes comprising the Vancouver Island Ranges. The relationship between forest zone and soil great groups is also demonstrated by Jungen (1985) in the Soils of Southern Vancouver Island (Figure 7).

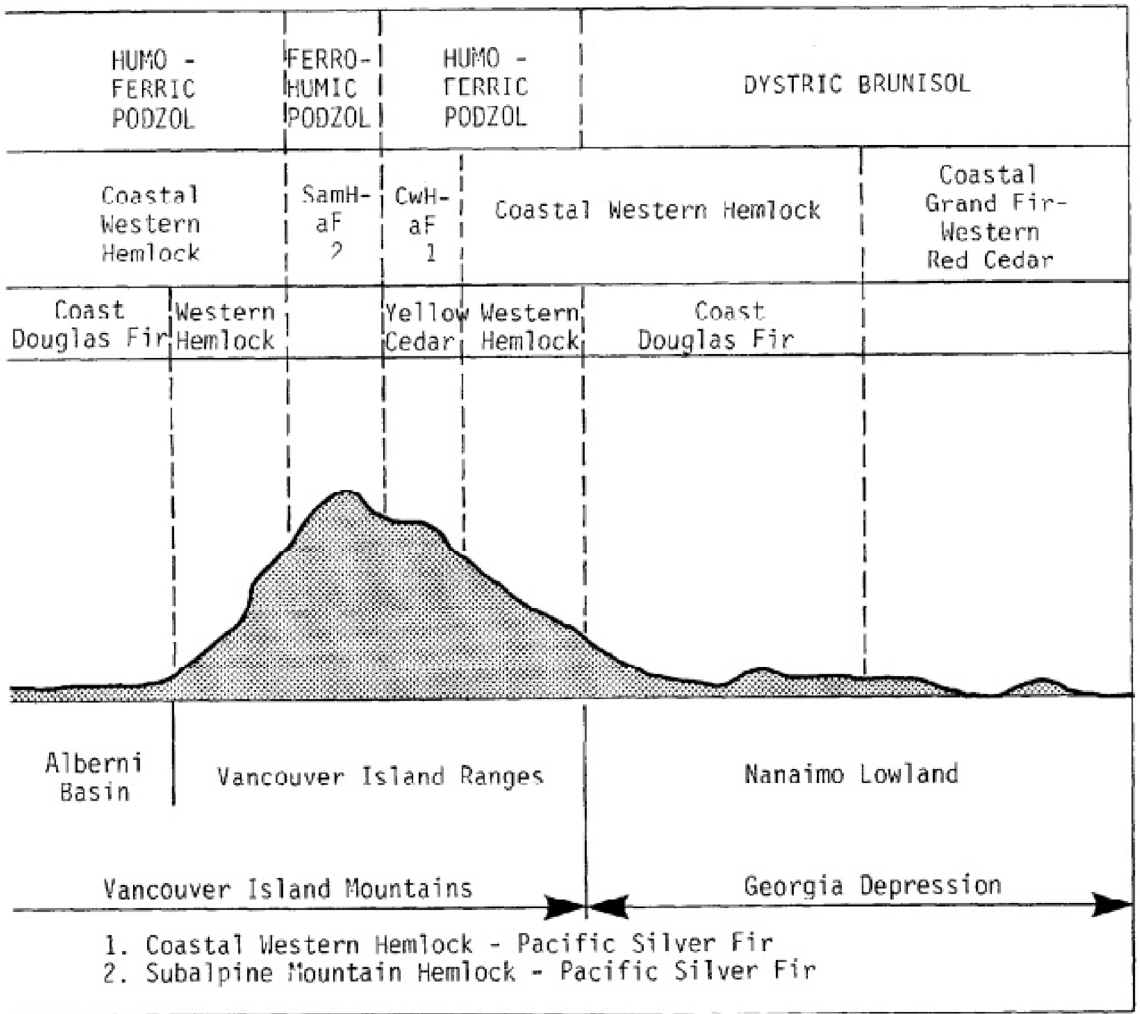

FIGURE 7. Soil great groups and forest zones for the Nanaimo Lowland and Vancouver Island Ranges – from Jungen 1985.

Generally observed soil orders in the study area and their relative landform location are described as follows:

Brunisols

Brunisols, which are differentiated from Podzols as having insufficient accumulation of organic matter, aluminum, and iron in the 'B' horizon, occur in all parent materials in this area according to Jungen et al. (1989) however, the most common parent materials are marine (generally veneered) over glacial till (St. Mary and Trincomali soil series) or glacial till (Mexicana soils). To the south of the study area, the Beddis soil series (a Brunisol) is mapped in proximity to streams (on terraces) flowing towards the ocean, having developed from fluvial and marine parent materials.

PHOTO 13. Brunisol observed in a gentle, imperfectly drained forest along Arden Road, Courtenay. This is plot JMV048.

A soil possibly conforming to the Royston soil series (a Brunisol that developed from till parent materials) was observed in the northern extent of the study area along Arden Road (Photo 13). Soils that also appeared to conform to the Brunisolic order were observed on gentle, marine and till slopes above the Trent River (Plot JMV033).

PHOTO 14. Regosol along Hart Creek (plot JMV041), which is also called Washer Creek locally in this area. Note mound to the right of the photo is coal waste in Union Bay.

<u>Regosols</u>

These soils were observed primarily along river plains (Photo 14) and gently sloping river terraces throughout the study area. There is still deposition of sediment (via overbank flooding) or erosion by gravity (in the case of steep slopes) or floodwaters; these act to limit soil development. Areas where organic matter can accumulate (*i.e.*, infrequent flooding) have enriched Ah horizons (Humic Regosols). The soils are coarse textured, most commonly cobbly, gravelly loamy sands. Although near rivers and deltas, the coarse soils are rapidly drained with variable watertables, depending on the season. Polygons mapped and field checked with these soils tend to have drainages indicated as ‘r, v’ or ‘r, p’ (rapidly or very poorly drained, rapidly or poorly drained, with no intermediate drainage classes present).

Podzols

According to Jungen et al. (1989), Podzolic soils occur in wetter or higher elevation zones in this area, and in association with coniferous vegetation that supplies acidic organic matter. They can be difficult to differentiate from Brunisols in the field due to similar colours (acidic, yellowish red, illuvial B horizons); chemical analysis of extractable aluminum is often required to confirm which soil order the soil belongs to. Well-defined Ae horizons are observed in Podzols that have developed from coarse-grained glaciofluvial materials in the study area (Jungen et al. 1989).

PHOTO 15. Podzol observed along a steep slope with overlying colluvial blanket at plot JMG015, on the upland site to the south of Comox Lake.

Sandy loam soils believed to be Podzols were observed on upland glacial till and colluvial mountain slopes along the west margin of the study area (Photo 15 and 16) near Comox Lake.

The soils may conform to the Rossiter (colluvium), Quimper (till), and Cullite (till) soil series described by Jungen (1985). These soils featured Mor humus forms and were classed 2C to 3C for soil nutrient and soil moisture regime.

PHOTO 16. Possible podzol observed in glacial till parent materials near Comox Lake. Note that the black material is a decaying log.

Another commonly mapped and observed Podzol in the study area conforms to the Quennell soil series (Photo 17). This was observed in glaciofluvial sediments to the east of Comox Lake. This soil is also found in association with the Quinsam soil, which is a Podzol that has developed from a blanket of glacial till parent materials. These soils have an SMR/SNR of 2B to 3B and a humus form of Mor.

PHOTO 17. Loamy sand soil observed east of Comox Lake at plot JMG018. This conforms to the Quennell soil series mapped by Jungen et al. (1985).

Organic soils

Organic soils were observed around wetlands and depressional areas in the primarily the northern half of the study area. A humisol (dark brown to black, well-decomposed, deep, and very poorly-drained) was observed in the Morrison Creek area (Photo 18). This conforms well to the Metchosin soil series mapped by Jungen et al. (1985).

PHOTO 18. Organic soil observed in the Morrison Creek area, adjacent to Lake Trail Road in the northern half of the study area. This is plot JMG051.

The overall trends in soils richness (soil nutrient regime, SNR) in the study area are as follows:

- the rich sites (SMR of D and E, Mull humus forms) are found along the east margins of the study area near the ocean (within marine deposits, such as the upland area around Millard Creek, Photo 19) and around fluvial plains (Trent River, Millard Creek, Washer Creek, Cook Creek, Photo 20);
- medium to poorer sites (SNR of C to B) on are found on glaciofluvial plains and terraces or in higher elevation areas featuring a veneer of marine deposits overlying glacial till; and
- sites to the west and higher were medium in richness (C) except for seepage sites with western redcedar that were richer (e.g. Site Series 07, plot HWG060).

PHOTO 20. Another rich site observed near Cook Creek in the south part of the study area (SMR/SNR of 6E). This is plot HWG006.

PHOTO 19. Rich site observed in Millard Creek Park (5D for SMR/SNR). This is plot JMG028.

More detailed field assessments would likely result in observations of Gleysols. Gleysols are likely found in proximity to the mapped wetlands, within glaciomarine parent materials. There is very minor glaciolacustrine in the study area; Gleysols are likely found here as well (east of Comox Lake and near Bradley Lake).

3.6.3.1 Impact of Harvesting on Humus Form

It is possible that as a result of ground-based forest harvesting on the predominant gentler site conditions of the study area (slopes <45%), the LFH horizons have been disturbed to the point that Mull and Moder forms are not being accurately represented (*i.e.*, these humus forms existed in areas prior to forest harvesting but were destroyed by ground-based harvesting via skidding logs and hoe-chuck machinery).

As such, there may be sites with slightly more rich nutrient regimes not being captured due to compaction and erosion of the LFH and Ah horizons (2 cm being a defining value and easily lost through site disturbance such as heavy machinery and dragging logs). Furthermore, on the imagery and in the field, we observed areas where logging had been conducted in a ‘strip’ like fashion. In one field plot (JMV053, near Morrison Creek in the north part of the study area), this resulted in alternating dry and wet strips of land, potentially skewing the soil moisture regime depending where the plot was taken.

4 Discussion

4.1 Potential Applications of TEM

There are many potential applications of ecosystem mapping that could be of value to LWRS, the BCCF and CDFCP regarding management priorities and conservation planning. Some of the key uses include identifying aquatic habitats including fish habitat, active fluvial units, upland stream areas and sensitive watersheds, providing insight on sensitive ecosystems that may be red- or blue-listed, and informing land use decisions which may include forestry activities. Other uses include interpretation of potential habitat values (suitability) for species of management priority.

4.1.1 Ecosystems at Risk

The mission of the CDFCP is “to promote the conservation and stewardship of the Coastal Douglas-fir and associated ecosystems in south-western British Columbia”. This TEM product can be used to support an understanding of the current distribution and representation of ecosystems at risk within the CWHxm1. The B.C. Conservation Data Centre (CDC) uses the term “ecological community” to capture the full range of ecosystems in B.C. at a variety of levels including both forested and non-forested ecosystems[8].

In B.C. ecological communities at risk are those that have been assigned a status rank of red-listed (extirpated, endangered or threatened) or blue-listed (special concern). It is important to note that ecological communities are defined from their plant associations and not a site series.

[8] B.C. Conservation Data Centre. https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data/faq Web. (Accessed September 7, 2022).

A site series is a location on the ground that has the potential to produce a particular plant association. It can be identified even when there is no vegetation present. However, in order to identify the ecological community, the characteristic vegetation and physiognomic structure must be present. This makes it difficult to infer that the ecological community is present solely by identifying the site series. On the B.C. Species and Ecosystem Explorer (BCSEE) the B.C. CDC lists the site series from published BEC Field Guides, on which an ecological community is known to occur but currently, only field verification will confirm if the plant association of the ecological community at risk is present. Further, not all ecological communities at risk have an associated site series. For example, the ecological community arbutus/hairy manzanita does not have an associated site series but is described in the BC Species and Ecosystems Explorer and has been mapped in the CWHxm1 and CDFmm.

Non-forested ecological communities at-risk mapped in the study area include:

- Tufted hairgrass – meadow barley estuary meadow (Ed01) – red-listed
- Tufted hairgrass – Douglas' aster estuary meadow (Ed02) – red-listed
- Beaked ditch-grass estuary marsh (Em01) – red-listed
- Sitka sedge/peat-moss fen (Wf51) – red-listed
- Common cattail marsh (Wm05) – blue-listed
- Sitka willow – Pacific willow/skunk cabbage swamp (Ws51) – red-listed
- Arbutus/hairy manzanita (00) – red-listed

Red- or blue-listed forested ecological communities occur throughout the mapped area. The plant communities associated with all forested site series in the CWHxm1 are considered ecological communities at risk, except for the Douglas-fir - lodgepole pine / grey rock-moss community, which is known to occur on the CWHxm1/02. Further assessment of these ecological communities will be required to confirm their delineation as they were not all field verified.

While this TEM product provides a starting point for delineating ecological communities at risk it is important to first query the BCSEE for potential ecological communities that may occur in a study area. By identifying all potential ecological communities that may exist and their plant associations, the TEM can be used to focus field surveys in areas with high potential for occurrence. All ecological communities at risk that are identified, and particularly mapped following RISC standards, should be submitted to the B.C. CDC so they can be evaluated as potential element occurrences and become publicly available.

4.1.2 Sensitive Ecosystems

The TEM could also provide information to support BCCF and CDFCP by identifying sensitive ecosystems (RISC 2006). Polygons attributed during previous phases of the mapping had SEI labels assigned. During the QA phase, these labels were reviewed and updated where appropriate to reflect any updates in the mapping. However, SEI labels were not assigned to the remaining polygons in the study area. Through the development of a crosswalk table, similar to the Realm/Group/Class lookup table prepared for this project, SEI labels could be assigned to the relevant ecosystems within the TEM. Although SEI is typically completed at a finer scale (1:5,000), this process could highlight areas for further refinement of the mapping if required. Some of the SEI classes that would be identified through this process within the CWHxm1 TEM – Southern CVRD include Herbaceous (HB), Intertidal (IT), Mature Forest (MF), Freshwater (FW), Riparian (RI), Sparsely Vegetated (SV) and Wetland (WN).

4.1.3 Aquatic Habitats

The major fluvial unit mapped in this TEM study area is the Puntledge River. The Puntledge River drains Comox Lake and enters the ocean in the City of Courtenay. The Trent River and some smaller rivers were also mapped, which all drain east into the ocean and provide low-gradient habitat for fish within their estuaries and lower reaches. There were also a some low-gradient streams with extensive wetland complexes associated with them, including Morrison Creek, which is known to support the endemic Morrison Creek lamprey (*Lampetra richardsoni var. marifuga*). Wetlands that are too small to support fish can provide good aquatic habitat for amphibians, as well as other wildlife species including birds and small mammals.

4.1.4 Land Use Planning

The TEM product can also be useful for land use planning at both the local and provincial levels, as it contains both ecosystem and terrain attributes. Some of the possible planning uses and what specific data from the TEM is relevant to that use are described in the following sections.

4.1.4.1 Forestry

With respect to forestry, the ecosystem label (site series) can identify where productive forest is located and what stage of development the forest is at, which can be useful for forest harvesting planning and road construction planning.

The terrain labels can also help identify any challenges that may occur regarding the cutblock layout, specifically where the soils are thin over bedrock (erosion potential for road construction), where the terrain is steep and where there may be significant colluvium (loose rock). Alternatively, terrain labels associated with gentle to moderate slopes (j and a), shallow glacial till (Mv), colluvial blankets, and near-surface or at surface bedrock may be ideal locations for forest road construction, in particular new construction, to avoid sensitive ecosystems or ecosystems at risk described in the report section above.

4.1.4.2 Ecological Restoration

Areas identified as having disturbances due to recreation could be prioritized as restoration areas, particularly for native plants. Non-native species are generally found near major recreational routes and trails, for example the Puntledge River and Trent River Greenway in Courtenay, Coal Creek Historic Park and Community Forest in Cumberland and the Seaside Trail in Royston. These high-traffic areas can be opportunities for restoration activities including invasive plant removal, garbage clean-up, and replanting with native species.

4.1.5 Wildlife Habitat Ratings

Wildlife habitat ratings are used to define the relative importance of various ecological units to wildlife. The ratings reflect a habitat's potential to support a particular species by comparing it to the best available for that species in the province (benchmark habitat). Habitat models can be created based on TEM with values assigned to ecosystems and structural stages. Habitat models can be used to determine how much suitable habitat is available for a given species or plant or ecosystem of interest. The models can also be very useful in guiding development of field sampling plans for specific species.

5 Conclusion

The project area contains a diverse range of forested and non-forested ecosystems. Disturbance was high in accessible areas, primarily due to forest harvesting and recreation-related effects. Although no old forest was mapped via on-screen interpretation of 3D imagery or field plots, some pockets of old forest may occur on steep north-facing slopes south of Comox Lake or in gullies. Several non-forested estuarine and wetland units mapped may represent ecological communities at risk, though these will require further assessment for verification and working with the BC CDC to confirm that they meet the requirements for tracking as element occurrences of ecosystems at risk.

Overall, this TEM product improves coverage of Ecosystem Inventory and Mapping of CWHxm1 TEM with a total of 1,806 ecosystem polygons delineated over 33,274.88 ha. A total of 120 plots were collected in the study area between March 28 and April 8th, 2022. All field crews consisted of a bioterrain/soils professional and a terrestrial ecosystem ecologist. Based on the final linework the sampling met the project goals (SIL 5, 6.6%). The average polygon size was 18.42 ha, but exclusion of the largest polygons (lake, urban, rural, industry-related and cultivated fields) would result in a smaller average polygon size.

The mapping was provided as a stand alone product for the Southern CVRD study area (BAPID 6641) and as an update to the existing CWHxm1 TEM (BAPID 6544). Linework edits to the CWHxm1 TEM resulted in a total of 19,289 polygons covering 264,346.86 ha. All products were produced in accordance with current RISC standards and guidelines for submission to the provincial TEM data custodian. This information can be used as a tool to inform land base investments and resource management decision-making. If additional funding is approved, recommendations include further completion of the polygon attribution (labeling) for the CWHxm1 TEM coverage (BAPID 6544).

6 Literature Cited

Alley, N.F., and S.C. Chatwin. 1979. Late Pleistocene history and geomorphology, southwestern Vancouver Island, British Columbia. Can. J. Earth Sci. 16, 1645–1657.

Clague, J.J., Harper, J.R., Hebda, R.J., and D.E. Howes. 1982. Late Quaternary sea levels and crustal movements, coastal British Columbia. Canadian Journal of Earth Sciences. 19(3): 597-618.

Clague, J.J. and B. Ward. 2011. Pleistocene Glaciation of British Columbia. Developments in Quaternary Science. 15. 563-573.

Green, R. K. and K. Klinka. 1994. A Field Guide to Site Identification and Interpretation for the Vancouver Forest Region. 2nd edition. Land Management Handbook 28. Research Branch Ministry of Forests. Victoria, BC.

B.C. Conservation Data Centre. https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data/faq Web. (Accessed September 7, 2022).

British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment (BCMFR and BCMOE). 2010. Field Manual for Describing Terrestrial Ecosystems- 2nd Edition. BCMFR Research Branch and BCMOE Resource Inventory Branch, Victoria, B.C. (Reprint with updates 2015).

Fyles, J.G. 1960. Surficial Geology, Courtenay, Comox, Nelson, Nanaimo and Newcastle Districts, Vancouver Island, British Columbia. Geological Survey of Canada, Preliminary Map 32-1960, 1960, 1 sheet.

Hebda, C., McLaren, D., Mackie, Q., Fedje, D., Pedersen, M., Willerslev, E., Brown, K., and R. Hebda. 2022. Late Pleistocene palaeoenvironments and a possible glacial refugium on northern Vancouver Island, Canada: Evidence for the viability of early human settlement on the northwest coast of North America. Quaternary Science Reviews. 279. 107388.

Holland, S.S. 1976. Landforms of British Columbia: A Physiographic Outline. Issue 48 of Bulletin British Columbia. Department of Mines and Petroleum Resources.

Howes, D.E. 1981. Late Quaternary sediments and geomorphic history of north-central Vancouver Island. Can. J. Earth Sci. 18, 1–12.

Jungen, J.R., Sanborn, P., and P.J. Christie. 1985. Soils of Southeast Vancouver Island: Duncan-Nanaimo Area. MOE Technical Report 15. Ministry of Environment, Ministry of Agriculture and Food.

MacKenzie, W.H. 2012. Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in British Columbia. Ministry of Forests, Lands and Natural Resource Operations, Victoria, B.C. Technical Report 068.

Madrone Environmental Services Ltd (Madrone). 2021a. Terrestrial Ecosystem Mapping for the CWHxm1 in the West Coast Region – Phase 2. Duncan, BC.

Madrone Environmental Services Ltd (Madrone). 2021b. Terrestrial Ecosystem Mapping for the CWHxm1 in the West Coast Region – Phase 3. Duncan, BC.

Madrone Environmental Services Ltd (Madrone). 2020. Terrestrial Ecosystem Mapping for the CWHxm1 in the West Coast Region – Phase 1 (Linework). Duncan, BC.

Madrone Environmental Services Ltd (Madrone). 2008. Terrestrial Ecosystem Mapping of the Coastal Douglas-Fir Biogeoclimatic Zone. Duncan, BC.

Massey, N.W.D., Desjardins, P.J. and E.C. Grunsky. 1994. Vancouver Island (92B, C, E, F, G, K, L; 102I). British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 1994-6.

Resources Inventory Committee (RIC). 1998. Standard for terrestrial ecosystem mapping in British Columbia. Ecosystems Working Group, Resources Inventory Standards Committee. Victoria, B.C. Site Accessed: March 2017

Resource Inventory Standards Committee (RISC) 2015. Terrestrial Ecosystem Information (TEI) Digital Submission Standard: Version 1. BC Ministry of Environment – Ecosystems Branch. Victoria, BC.

Resources Information Standards Committee (RISC). 2006. Standard for Mapping Ecosystems at Risk in British Columbia: An approach to mapping ecosystems at risk and other sensitive ecosystems. Version 1.0 Prepared by Ministry of Environment, Ecosystems Branch, Victoria, B.C.

Terrestrial Ecosystem Information (TEI) Unit. 2022. Terrestrial Ecosystem Information (TEI): Ecosystem Mapping Code List. Version 2.1. Ministry of Environment and Climate Change Strategy, Knowledge Management Branch, Ecosystem Information Section. February, 2022.

Terrestrial Ecosystem Information (TEI) Unit. 2020a. Terrestrial Ecosystem Information (TEI): Coding Updates for Non-Vegetated, Sparsely Vegetated, and Anthropogenic Units. Version 1.1. Ministry of Environment and Climate Change Strategy, Knowledge Management Branch, Ecosystem Information Section

Terrestrial Ecosystem Information Unit. 2020b. Contractor Package_20200319 – Draft for Testing. Ministry of Environment and Climate Change Strategy, Knowledge Management Branch, Ecosystem Information Section. Victoria, B.C.

APPENDIX I: Map Code Legend

BGC_ZONE	BGC_SUBZON	BGC_VRT	BGC_PHASE	BGC_Label	SITE_S	SITEMC_S	Site Series Name	REALM	GROUP	CLASS	KIND	Ecosystem Type and Subtype	Ecosystem Description	DRAIN	Slope/Aspect	STS_Range	STS_Climax	SComp_Climax
CWH	xm	1		CWHxm1	01		HwFd - Kindbergia	T	T		M	Forested Forest	gentle slope; deep medium - textured soils	w	gentle	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	02		FdPl - Cladina	T	T		M	Forested Forest	gentle slope; crest position; medium textured shallow soil	x,r	gentle to level	2,3,4,5,6,7	7	C
CWH	xm	1		CWHxm1	03		FdHw - Salal	T	T		M	Forested Forest	significant slope, upper slope position; warm aspect, deep medium - textured soils	r	moderately steep to steep, warm aspect	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	04		Fd - Sword fern	T	T		M	Forested Forest	significant slopes, deep medium - textured soils; richer nutrient regime (use aspect modifiers)	r	moderately steep to steep	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	05		Cw - Sword fern	T	T		M	Forested Forest	significant slope, deep medium - textured soils; richer nutrient regime (use aspect modifiers)	r,w	moderately steep to steep	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	06		HwCw - Deer fern	T	T		M	Forested Forest	gentle slope; lower slope position; receiving moisture; deep medium-textured soil	w,m	gentle	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	07		Cw - Foamflower	T	T		M	Forested Forest	gentle slope; lower slope position, receiving moisture; deep medium - textured soil; richer nutrient regime	w,m	gentle	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	08		Ss - Salmonberry	T	F	h	M	Forested Flood	high bench floodplain sites	w,m	gentle	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	09		Act - Red-osier dogwood	T	F	m	M	Forested Flood	active floodplain, middle bench, deep medium - textured soil. *This unit is equivalent to Fm50 - Act - Red alder - Salmonberry when structure is < 10m.	m,i,p	level	2,3,4,5,6	6	M
CWH	xm	1		CWHxm1	11		Pl - Sphagnum	W	P	b	O	Wetland Bog	organic wetland, bog woodland, forested bog	i,p,v	depression	2,3,4,5,6,7	7	C
CWH	xm	1		CWHxm1	12		CwSs - Skunk cabbage	W	M	s	M	Wetland Swamp	treed swamp, poorly drained , depression to flat, deep medium - textured mineral soil	i,p,v	depression	2,3,4,5,6,7	7	C
CWH	xm	1		CWHxm1	13		Cw - Salmonberry	T	T		M	Forested Forest	strongly fluctuating water table, deep medium - textured mineral soil	m,i,p	level	2,3,4,5,6,7a,7b	7b	C
CWH	xm	1		CWHxm1	15		Cw - Slough sedge	W	M	s	M	Wetland Swamp	strongly fluctuating water table, deep medium - textured mineral soil	m,i,p	depression	2,3,4,5,6,7	7	C
CWH	xm	1		CWHxm1	Bb	Bb	Beachland	T	B	b	M	NonForested Beachland	Occur on unconsolidated marine sediments in the supratidal zone. Areas are affected by salt spray, wind and/or water erosion, and deposition of marine sediments. Halophytes and graminoid species adapted to erosion and burial by shifting sands are common in the beach and foredune zones. Ecosystems of stabilized dune deposits are included in this class and may have higher cover of shrubs and mosses.	i,p,v	gentle to level	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Ed	Ed	Estuarine Meadow	E	E	d	M	Wetland Estuary	Occur in the high intertidal zone of estuaries, where tidal flooding occurs less frequently than daily and is tempered by freshwater mixing. Species composition is relatively diverse, typically with a mix of graminoids and forbs	i,p,v	level	1,2	2	

CWH	xm	1		CWHxm1	Ed01	Ed01	Tufted hairgrass - Meadow barley	E	E	d	M	Wetland Estuary	Occurs throughout the coast in the upper intertidal zone on fan estuaries, on creekside areas within moderate-sized estuaries and as narrow fringes on steep coastal shores with abundant groundwater seepage. These sites experience daily but generally brief flooding by brackish water	i,p,v	gentle to level	2a,2b	2	
CWH	xm	1		CWHxm1	Ed02	Ed02	Tufted hairgrass - Douglas' aster	E	E	d	M	Wetland Estuary	Widespread, occurring medium to large estuaries. Occurs in the high marsh zone between the backshore shrub communities and the low marsh, usually in broad and extensive flats. Limited to zones within the estuary where weakly brackish conditions predominate and inundation is irregular	i,p,v	gentle to level	2a,2b	2	
CWH	xm	1		CWHxm1	Em	Em	Estuarine Marsh	E	E	m	M	Wetland Estuary	Intertidal ecosystem that is flooded diurnally and has simple communities dominated by salt-tolerant emergent graminoids and succulents. Occur in the middle to upper tidal zones of estuaries that have a strong saltwater influence.	i,p,v	gentle to level	2a,2b	2	
CWH	xm	1		CWHxm1	Em01	Em01	Widgeon-grass	E	E	m	M	Wetland Estuary	Common throughout coastal BC. Occurs in brackish, mud-bottomed pools, lagoons, backwater sloughs, drainage channels and mudflats that dissect lower portions of estuarine marshes. Tidal inundation is usually prolonged. Sites are often small in extent but can occasionally occur over large areas of tidal flats where sedimentation rates are low.	i,p,v	gentle to level	2a,2b	2	
CWH	xm	1		CWHxm1	Et	Et	Estuarine Tidal Flat	E	E	t	M	Wetland Estuary	Intertidal ecosystems dominated by benthic/burrowing fauna and macroalgae. These ecosystems occur in the mid to lower tidal zones of estuaries, where freshwater and salt water mix. Sites are flooded and exposed with most tidal cycles. Large flats of silts, sands or pebbles are common.	i,p,v	gentle to level	1	1	
CWH	xm	1		CWHxm1	Fa	Fa	Active channel flood	T	F	a	M	NonForested Flood	Occur on sites that are annually flooded, and often scoured for prolonged periods. Sites are usually immediately adjacent to the river channel at lower water conditions. On unstable substrates, such as gravel bars and islands, ecosystems are usually dominated by annuals or herb-layer species with extensive root systems. Bryoid communities are more typical on active channel sites with more stable substrates.	m,i,p	level	1,2	2	
CWH	xm	1		CWHxm1	Fl	Fl	Low bench flood	T	F	l	M	NonForested Flood	Occur on sites that are flooded for moderate periods (<40 days) of the growing season - conditions that limit the canopy to tall shrubs, especially willows or alders. Annual erosion and deposition of sediments generally limit the understorey and humus development. Commonly associated with fluvial systems but also occur on wave-washed beaches of larger lakes.	m,i,p	level	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Ro	Ro	Rock Outcrop	T	R	o	N	NonForested Rock	Bluffs and knobs of bedrock with limited soil development and high cover of exposed rock. Drought-tolerant cryptograms are often prominent and vascular plants are limited.	x,r	gentle to steep	1,1a,1b,2a,2b	2	
CWH	xm	1		CWHxm1	Rt	Rt	Rock Talus	T	R	t	N	NonForested Rock	Slopes covered by angular rocks and stones that have been moved by gravity downslope from rock outcrops.	x,r	level to moderate	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Wb	Wb	Bog	W	P	b	O	Wetland Bog	Bogs are nutrient-poor, Sphagnum dominated peatland ecosystem in which the rooting zone is isolated from mineral-enriched groundwater, soils are acidic and few minerotrophic plant species occur.	p,v	level or depression	1,1a,1b,2,3a,3b	3b	

CWH	xm	1		CWHxm1	Wf	Wf	Fen	W	P	f	O	Wetland Fen	Fens are nutrient-medium peatlands dominated by sedges and brown mosses, where mineral-bearing groundwater is within the rooting zone and mesotrophic plant species are common. Fens develop along lake margins and adjacent to slow-moving streams, where the water table is usually at or just below the peat surface for most of the growing season. Fens often occur in association with swamp ecosystems.	p,v	level or depression	2a,2b,3a,3b	3b	
CWH	xm	1		CWHxm1	Wf51	Wf51	Sitka sedge - Peat-moss	W	P	f	O	Wetland Fen	Occur at low elevations along the coast in wet drainage channels or hollows in sloping peatlands where there is gradually flowing surface water. Carex in dense swards with Sphagnum in carpets or floating in shallow water. Peat accumulations range from thin veneers to deep blankets.	p,v	level or depression	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Wm	Wm	Marsh	W	M	m	M	Wetland Marsh	A permanently to seasonally flooded non-tidal mineral wetland that is dominated by emergent grass-like vegetation. A fluctuating water table is common, with water tables typcially dropping through the growing season. Likely to occur on larger water bodies in localized areas.	p,v	level or depression	2a,2b	2	
CWH	xm	1		CWHxm1	Wm05	Wm05	Cattail	W	M	m	M	Wetland Marsh	Common at low elevations and occur most commonly in protected lake embayments and potholes or even roadside ditches, where the surface substrate remains saturated for most of the growing season. Often have organic veneers of well-decomposed, odiferous muck. Water depths may be up to 1 m in the spring but recede in late summer, sometimes to the surface.	p,v	level or depression	2a,2b	2	
CWH	xm	1		CWHxm1	Ws	Ws	Swamp	W	M	s	M	Wetland Swamp	Nutrient-rich wetland where significant groundwater inflow, periodic surface aeration and/or elevated microsites allow the growth of trees or tall shrubs under subhydric conditions. Often have surface standing water and may be underlain with peat, but it is well decomposed, woodey and dark coloured. Swamps tend to occur at the periphery of peatland ecosystems in the transition to upland.	p,v	level or depression	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Ws50	Ws50	Hardhack - Sitka sedge	W	M	s	M	Wetland Swamp	Common at low elevations in basins, gullies and margins of waterbodies and peatlands. Experience prolonged saturation and brief early-season flooding	p,v	level or depression	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Ws51	Ws51	Sitka willow - Pacific willow - Skunk cabbage	W	M	s	M	Wetland Swamp	Occur sporadically at low elevations and in floodplain depressions. *S. sitchensis* and *S. lucida* co-dominate a closed canopy of tall shrubs and low trees. Understore is lush and dominated by lady fern and skunk cabbage. The moss layer is typically sparse.	p,v	level or depression	1,1a,1b,2,3a,3b	3b	
CWH	xm	1		CWHxm1	Ww	Ww	Shallow Water	W	M	w	M	Wetland Shallow Water	Aquatic ecosystems that are permanently flooded by still or slow moving water and are dominated by rooted, submerged, and floating aquatic plants. Occur most commonly where standing water is <2 m deep in midsummer. Aquatic plants may root in mineral soils or in well-humified sedimentary peat.	p,v	level or depression	0,2c	2c	
CWH	xm	1		CWHxm1	00	AM	Ra - Hairy Manzanita	T	T		M	Forested Forest	These sites are typically on bedrock outcrops and ridge crests with warm aspects. Slopes are gentle to moderate, and soils are thin and rapidly drained. Arbutus is always present, and manzanita common in open areas. In the study area, this unit was only mapped as non-forested (shrub)	x,r	gentle to level	2,3,4,5	5	B

CWH	xm	1		CWHxm1		CF	Cultivated Field	T	X	a	M	Anthropogenic Agricultural	A flat or gently rolling, non-forested, open area that is subject to human agricultural practices (including plowing, fertilization and non-native crop production) which often result in long-term soil and vegetation changes.	w,m	N/A	1,2,3	3	
CWH	xm	1		CWHxm1		CX	Corridor/Industry-Related Disturbance	T	X	a	U	Anthropogenic Disclimax	Areas of recent human-made disturbance due to road rights-of-ways including temporary/ abandoned roads and associated right-of-ways, transmission lines, pipelines, seismic activity or other industry-related disturbance. These sites can be non or sparsely-vegetated but typically the vegetation cover is maintained in earlier seral stages.	variable	N/A	1,2,3	3	
CWH	xm	1		CWHxm1		DZ	Dam	T	X	a	N	Anthropogenic Land Cover	Hydroelectric dam actively used for power production	N/A	N/A	0	0	
CWH	xm	1		CWHxm1		ES	Exposed Soil	T	X	a	M	Anthropogenic Disclimax	Any area of exposed soil that is not included in any of the other definitions and is non-anthropogenic (or uncertain) in origin. It can include areas of recent disturbance where vegetation cover is <5%.	variable	N/A	1	1	
CWH	xm	1		CWHxm1		GP	Gravel Pit	T	X	a	N	Anthropogenic Disclimax	A non-vegetated area exposed through the removal of sand and gravel.	x	N/A	1	1	
CWH	xm	1		CWHxm1		LA	Lake	O			N	NonVegetated Water	A naturally occurring static body of water, 10 ha or greater in size and at least 2 m deep in some portion.	v	level	0	0	
CWH	xm	1		CWHxm1		MS	Mine Spoil	T	X	a	M	Anthropogenic Disclimax	A non-vegetated area of discarded rubbly overburden or waste rock moved so that ore can be extracted in a mining operation.	x,r	N/A	1	1	
CWH	xm	1		CWHxm1		PD	Pond	O			N	NonVegetated Water	A small naturally occurring static body of water, less than 10 ha in size and at least 2 m deep in some portion. Not large enough to be classified as a lake but typically larger/ deeper than shallow water wetlands and are non-vegetated	v	depression	0	0	
CWH	xm	1		CWHxm1		RI	River	O			N	NonVegetated Water	A watercourse formed when water flows between continuous, definable banks. The flow may be intermittent or perennial. An area that has an ephemeral flow and no channel with definable banks is not considered a river. Use Floodplain Active Channel (Fa) for smaller drainages and/or gravel bar features.	r	N/A	0	0	
CWH	xm	1		CWHxm1		RM	Reclaimed Mine	T	X	a	M	Anthropogenic Disclimax	A reclaimed mined area that has plant communities composed of a mixture of agronomic or native grasses, forbs, and shrubs.	variable	N/A	2,3	3	
CWH	xm	1		CWHxm1		RP	Road Permanent	T	X	a	N	Anthropogenic Land Cover	An area cleared and compacted for the purpose of transporting goods and services by vehicle.	N/A	N/A	0	0	
CWH	xm	1		CWHxm1		RR	Rural Residential	T	X	a	U	Anthropogenic Land Cover	Any area in which residences and other human developments are scattered and intermingled with forest, range, farm land, and native vegetation or cultivated crops. Other units such as forested areas and cultivated fields should be mapped as separate units, where possible.	N/A	N/A	0	0	
CWH	xm	1		CWHxm1		UR	Urban/Suburban	T	X	a	N	Anthropogenic Land Cover	An area in which residences and other human developments form an almost continuous covering of the landscape (approximately ≥90% coverage). These areas include cities, towns, commercial and industrial parks, and similar developments. Other units such as forested areas should be mapped as separate units, where possible.	N/A	N/A	0	0	

Coniferous

Tree Codes	Tree Species
Cw	Western redcedar
Fd	Douglas-fir
Hw	Western hemlock
Pl	Lodgepole pine
Bg	Grand fir

Broad-leaved trees

Tree Codes	Tree Species
Qg	Garry oak
Ra	Arbutus
Dr	Red alder
Mb	Bigleaf maple
Act	Black cottonwood

Soil Moisture Definitions

Hydric	Wet, plants periodically or often inundated by water. Water removed so slowly that water table is at or above soil surface all year; gleyed mineral or organic soils.	SMR 8	very poorly drained (v)
Sub-hydric	Water removed slowly enough to keep water table at or near surface for most of year; gleyed mineral or organic soils; permanent seepage < 30 cm below surface	SMR 7	poorly drained (p)
Hygric	Water removed slowly enough to keep soil wet for most of growing season; permanent seepage and mottling; gleyed (greenish-blue-grey) colors common	SMR 6	imperfectly drained (i)
Sub-hygric	Water removed slowly enough to keep soil wet for a significant part of growing season; some temporary seepage and possibly mottling below 20 cm	SMR 5	moderately well-drained (m)
Mesic	Moist, adequate soil moisture retention year-round. Water removed somewhat slowly in relation to supply; soil may remain moist for a significant, but sometimes short period of the year. Available soil moisture reflects climatic inputs	SMR 4	well-drained (w)
Sub-mesic	Water removed readily in relation to supply; water available for moderately short periods following precipitation.	SMR 3	well-drained (w)
Sub-xeric	Moist to dry, seasonally moist, periodically dry. Water removed rapidly in relation to supply; soil is moist for short periods following precipitation	SMR 2	rapidly drained (r)
Xeric	Dry and drought resistant, little moisture retention, excessively drained -- May have multiple assignments. Water removed very rapidly in relation to supply; soil is moist for brief periods following precipitation	SMR 1	rapidly drained (r)
Very xeric	Water removed extremely rapidly in relation to supply; soil is moist for a negligible time after precipitation	SMR 0	very rapidly drained (x)

(From www.ncwildflower.org/index.php/plants/moisture/)

Structural Stages

0	Not Applicable
1	Sparse/cryptogam
1a	Less than 10% vegetation cover
1b	Bryophyte-dominated communities (greater than ½ of total vegetation cover)
1c	Lichen-dominated communities (greater than ½ of total vegetation cover)
2	Herb
2a	Forb-dominated
2b	Graminoid-dominated
2c	Aquatic
2d	Dwarf shrub

3	Shrub/herb
3a	Low shrub (<2m)
3b	Tall shrub (2-10m)
3c	Short stunted treed (<2m)
3d	Tall stunted treed (2-10m)
4	Pole/Sapling
5	Young Forest
6	Mature Forest
7	Old Forest
7a	Old Forest (productive) >250 years but <400 years
7b	Very Old Forest (productive) >400 years

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APPENDIX II: TEM Data Dictionary

Ecosections (ECO_SEC)

Code	Description
LIM	Leeward Island Mountains
NAL	Nanaimo Lowland
SOG	Strait of Georgia

Biogeoclimatic Units (Zone/Subzone/Variant) (BGC_ZONE; BGC_SUBZON; BGC_VRT)

Code	Description
CWHxm1	Eastern Very Dry Maritime Coastal Western Hemlock

Realm (REALM)

(As per *Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in British Columbia*, 2012)

Code	Name	Description
E	Estuarine	Intertidal sites at the confluence of streams and ocean and affected by brackish tidal water flooding.
O	Freshwater	Freshwater or inland brackish waters deeper than 2 m or shallow waters with < 10% rooted vegetation cover
T	Terrestrial	Upland sites characterized by vascular and non-vascular plants
W	Wetland	Semi-terrestrial sites with wetland soil and vegetation indicators or vegetated still waters < 2m in depth

Group and Class (GROUP and CLASS)

(As per *Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in British Columbia*, 2012)

Group	Class	Description
B	b	Beachland Group, Beachland Class
E	d	Estuarine Group, Meadow Class
E	m	Estuarine Group, Marsh Class
E	t	Estuarine Group, Tidal Flat Class
F	a	Flood Group, Active Class
F	l	Flood Group, Low Bench Class
F	h	Flood Group, High Bench Class
F	m	Flood Group, Middle Bench Class
M	m	Mineral Group, Marsh Class
M	s	Mineral Group, Swamp Class
M	w	Mineral Group, Shallow Water Class
P	b	Peat Group, Bog Class
P	f	Peat Group, Fen Class
R	o	Rock Group, Rock Outcrop Class
R	t	Rock Group, Talus Class
T		Treed Group
X	a	Disclimax Group, Anthropogenic Disclimax

Summary of KIND codes (KIND in 'TEI_User_Dfn_Fields')

(As per http://sis.agr.gc.ca/cansis/nsdb/soil/v2/snt/kind.html)

Codes	Class	Description
M	Mineral	The soil material is primarily composed of mineral particles.
O	Organic	The soil material is primarily composed of organic particles.
N	True Non-soil	This is a true non-soil (e.g., airport or lake).
U	Unclassified	This material was not classified due to an absence of information or an unusual situation, such as rockland or an extremely shallow soil.

Ecosystem Site Modifiers (SITE_MA; SITE_MB)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Modifier	Description
a	active floodplain
c	coarse-textured soils
g	gullying occurring
h	hummocky terrain
j	gentle slope
k	cool aspect (285 – 135°) slope (26% – 100%)
r	ridge
s	shallow soils (20-100cm)
t	terrace
w	warm aspect (135 – 285°) slope (26% – 100%)

Structural Stage (STRCT_S)
(As per *Structural_Stage_20220128.csv* and *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Structural Stage	Description
0 Not Applicable	For use with ecosystems where a structural stage value is not applicable (e.g. lakes, rivers, glaciers).
Post-disturbance stages or environmentally induced structural development	
1 Sparse/cryptogam	Initial stages of primary succession, or a very early stage of cohort establishment following a stand-destroying disturbance, or a cryptogam community maintained by environmental conditions (e.g., bedrock, boulder fields, talus); bryophytes or lichens can be dominant; time since disturbance is < 20 years for normal forest succession; sparse tree, shrub and herb cover: either sparsely vegetated overall (low cover of vascular plants and cryptogams, if present), or dominated by cryptogams.
Substages	
1a Sparse	Less than 10% vegetation cover.
Stand initiation stages or environmentally induced structural development	
2 Herb	Early successional stage or a herb community maintained by environmental conditions (e.g., very wet, warm & dry, or late snow site) or disturbance (e.g., avalanche track, flooding, intensive grazing, animal burrowing); generally dominated by herbs (forbs, graminoids, ferns), although herb cover can be low if sparsely vegetated overall as long as herbs characterize the vegetation; trees and shrubs are usually absent or sparse, however shrub cover and stature as compared to herb cover and stature determines whether the site is considered herbaceous; time since disturbance is < 20 years for normal forest succession; many non-forested communities are perpetually maintained in this stage.
Substages	
2a Forb-dominated	Herbaceous communities dominated (greater than 1/2 of the total herb cover) by non-graminoid herbs and ferns.
2b Graminoid-dominated	Herbaceous communities dominated (greater than 1/2 of the total herb cover) by grasses, sedges, reeds, and rushes.
2c Aquatic	Herbaceous communities dominated (greater than 1/2 of the total herb cover) by floating or submerged aquatic plants; sedge communities growing in marshes with standing water are classed as 2b.
3 Shrub/Herb	Early successional stage forest, or permanently shrubby sites where full stature trees will not develop due to environmental conditions (e.g., very shallow soils, high watertable, cold air accumulation) or disturbance (e.g., avalanche track); tree cover often sparse but tree seedlings and advance regeneration may be abundant; either dominated by shrubby vegetation, or if sparsely vegetated overall, shrub cover and stature characterizes the community as a shrubland.
Substages	
3a Low shrub	Communities dominated or characterized by shrub species < 2 m tall; recently established seral forests (commonly < 20 years since establishment for normal forest succession; or shrub species dominated ecosystems perpetuated indefinitely by environmental conditions (e.g., cold air basins) or disturbance.
3b Tall shrub	Communities dominated or characterized by shrub species 2 - 10 m tall; developing seral forests (commonly < 40 years since establishment for normal forest succession; or shrub species dominated ecosystems perpetuated indefinitely by environmental conditions (e.g., cold air basins) or disturbance.
Stem exclusion stages	
4 Pole/Sapling	Trees > 10 m tall, typically densely stocked, and have overtopped shrub and herb layers; younger stands are vigorous (usually > 15–20 years old); older stagnated stands (up to 100 years old) are also included; self-thinning and vertical structure are not yet evident in

Structural Stage	Description
	the canopy; time since disturbance usually < 40 years; up to 100+ years for dense (5000 – 15000+ stems per ha) stagnant stands.
5 Young Forest	Self-thinning has become evident and the forest canopy has begun to differentiate into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in the Pole/Sapling stage; begins as early as age 30 (e.g., broadleaf or vigorous conifer stands) and extends to 50–80 years, depending on tree species and ecological conditions; in forest stands at environmental extremes, a very open Young Forest structure may develop initially (single cohort) or over a period of time (multi-cohort) – use the ‘open’ modifier for such conditions.
Understorey reinitiation stage	
6 Mature Forest	Trees established after the last stand-replacing disturbance have matured; a second cycle of shade-tolerant trees may have become established; shrub and herb understories become well developed as the canopy opens up; time since disturbance is generally 80–140 years for BGCs with Natural Disturbance Type (NDT) 3 and 80–250 years for NDT 1, 2 & 4.

Stand Composition (STAND_A)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Stand Composition	Description
A description of the leaf-types of trees in a stand (only for structural stages 4-7)	
C	Coniferous (>75% of total tree cover is coniferous)
B	Broadleaf (>75% of the total tree cover is broadleaf)
M	Mixed (neither coniferous or broadleaf account for >75% of the total tree cover)

Disturbance Codes (DISTCLS)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Code	Description
L	Forest harvesting
L a	Forest harvesting, patch cut system
L c	Forest harvesting, clearcut system
L e	Forest harvesting, selection system
R	Recreation-related effects
R c	Recreation-related effects, camping
R m	Recreation-related effects, motorized trails
R p	Recreation-related effects, plant introductions
R t	Recreation-related effects, non-motorized trails
S	Soil disturbance
S a	Soil disturbance, cultivation (agricultural)
S f	Soil disturbance, sidecast/fill
S s	Soil disturbance, scalping (forest floor removed)
T	Terrain-related effects
W	Water-related effects

Terrain Texture Codes (TTEX_A, TTEX_B, TTEX_C)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Code	Name (size in mm)	Other Characteristics
c	clay (<0.002)	
g	gravel (>2)	mix of boulders, cobbles and pebbles
h	humic	decomposed organic material; (10%) identified after rubbing
k	cobble (64-256 mm)	rounded and subrounded particles
m	mud (<0.062)	mix of clay and silt
p	pebbles (2-64)	rounded and subrounded particles
s	sand (0.062-2.000)	
z	silt (0.002-0.0062)	

Surficial (genetic) Material Codes (SURFM)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010 and TEI Digital Data Standards, 2015)

Code	Name	Assumed Status	Description
A	Anthropogenic	(A)	Artificial or human-modified material
C	Colluvium	(A)	Products of mass wastage
F	Fluvial	(I)	River deposits
FG	Glaciofluvial	(I)	Ice contact fluvial material
L	Lacustrine	(I)	Lake sediments; includes wave deposits
LG	Glaciolacustrine	(I)	Ice contact lacustrine material
M	Till	(I)	Material deposited directly by glaciers
N	Not Classified		Used for areas that are not mapped for a variety of reasons
O	Organic	(A)	Accumulation/decay of vegetative matter
R	Bedrock	(-)	Outcrops/rocks covered by less than 10 cm of soil
W	Marine	(I)	Marine sediments; includes wave deposits
WG	Glaciomarine	(I)	Ice contact marine sediments

Surface Expression Codes (SURF_EA, SURF_EB, SURF_EC)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Code	Name	Description
a	Moderate slope	Unidirectional surface; >25% to <50%
b	Blanket thick	A mantle of unconsolidated materials; >1 m
d	Depression(s)	A lower area surrounded by a higher terrain
f	Fan(s)	A segment of a cone; up to 150
h	Hummock(s)	Hillocks and hollows; irregular in plan; 25% - 70%
j	Gentle slope	Unidirectional surface; >5% and <25%
k	Moderately steep slope	Unidirectional surface; >50% and <70%
p	Plain	Unidirectional surface; up to 5%
r	Ridge(s)	Elongate hillocks; 25-70%; parallel forms in plan view
s	Steep slope	Steep slopes; >70%
t	Terrace(s)	Step-like topography
u	Undulating	Hillocks and hollows; up to <25%; irregular in plan view
v	Veneer	Mantle of unconsolidated material; 0.1 to 1.0 m thick
x	Thin veneer about 2-20cm thick	A dominance of very thin surficial materials

Geomorphological Processes (GEOP_1, GEOP_2)

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Code	Name	Description
B	Braiding	Diverging/converging channels; unvegetated bars
F	Slow mass	Slow downslope movement of masses of cohesive or non-cohesive material
H	Kettle	Depressions in surficial material resulting from the melting of buried or partially buried glacier ice
I	Irregular channel	A single, clearly defined main channel displaying irregular turns and bends
L	Surface seepage	Zones of active seepage often found along the base of slope positions
R	Rapid mass movements	Rapid downslope movement of dry, moist, or saturated debris
U	Inundation	Seasonally underwater because of high water table
V	Gully erosion	Parallel/subparallel ravines caused by running water
W	Washing	Modification by wave action

Drainage

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Code	Name	Description
x	very rapidly drained	Water is removed from the soil very rapidly in relation to supply. Water source is precipitation and available water storage capacity following precipitation is essentially nil. Soils are typically fragmental or skeletal, shallow or both.
r	rapidly drained	Water is removed from the soil rapidly in relation to supply. Excess water flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall. Water source is precipitation. Soils are generally coarse textured.
w	well drained	Water is removed from the soil readily, but not rapidly. Excess water flows downward readily into underlying pervious material or laterally as subsurface flow. Water source is precipitation. On slopes, subsurface flow may occur for short durations, but additions are equaled by losses. Soils are generally intermediate in texture and lack restricting layers.
m	moderately well drained	Water is removed from the soil somewhat slowly in relation to supply because of imperviousness or lack of gradient. Precipitation is the dominant water source in medium- to fine- textured soils; precipitation and significant additions by subsurface flow are necessary in coarse-textured soils.
i	imperfectly drained	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Excess water moves slowly downward if precipitation is the major source. If subsurface water or groundwater (or both) is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season. Precipitation is the main source if available water storage capacity is high; contribution by subsurface or groundwater flow (or both) increases as available water storage capacity decreases. Soils generally have a wide range of texture, and some mottling is common.
p	poorly drained	Water is removed so slowly in relation to supply that the soil remains wet for much of the time that it is not frozen. Excess water is evident in the soil for a large part of the time. Subsurface or groundwater flow (or both), in addition to precipitation, are the main water sources. A perched water table may be present. Soils are generally mottled and/or gleyed.
v	very poorly drained	Water is removed from the soil so slowly that the water table remains at or near the surface for most of the time the soil is not frozen. Groundwater flow and subsurface flow are the major water sources. Precipitation is less important, except where there is a perched water table with precipitation exceeding vapotranspiration. Typically associated with wetlands. For organic wetlands, also evaluate the soil moisture subclass, and when entering on the form, separate from drainage by a slash. For example, v/ac.

Drainage Separator codes

(As per *Standard for Digital Terrain Data Capture*, 1998 and *Terrain Classification System for British Columbia*, 1997)

Map symbol	Definition
,	‘w, i’ indicates that no intermediate classes between well and imperfectly drained are present
-	‘w-i’ indicates that all intermediate classes between well and imperfectly drained are present.
.	components on either side of the symbol are of approximately equal proportion
/	r/p’ rapid drainage is dominant, poor drainage is sub-dominant
//	‘r//p’ rapid drainage is significantly dominant, poor drainage is minor